The Story of the Stars

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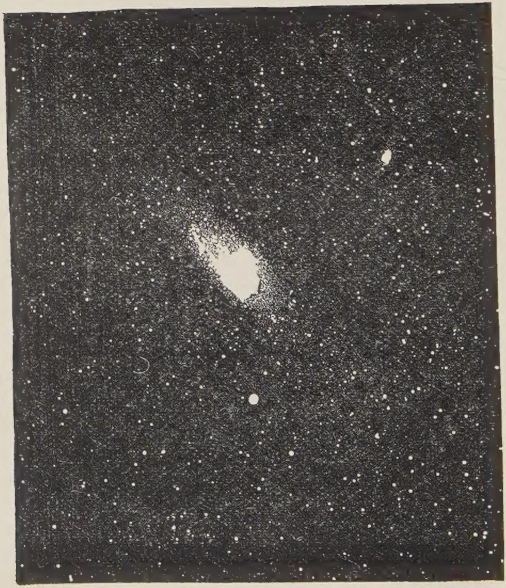
FIG. 1.



THE GREAT NEBULA IN ANDROMEDA.

(*Roberts.*)

THE STORY OF THE STARS

SIMPLY TOLD FOR GENERAL READERS.

BY

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PREFACE.

When invited to write this little book, I was asked so to shape it that it should be a concise but readable outline of that branch of knowledge which one associates with the expression the "Starry Heavens" liberally interpreted. I was to cater for those rapidly growing thousands of men and women of all ranks who are manifesting in these closing years of the nineteenth century in so many ways and in so many places an interest in the facts and truths of Nature and Physical Science. The task thus imposed upon me was a very congenial one, and I gladly undertook it. How far I have succeeded in presenting my facts in a bright and cheery spirit others must determine. But I would ask it to be understood that I have dealt with facts rather than fancies. There are too many of the former available for a writer on astronomy to make it worth while to waste space in dealing with the latter.

This volume will shortly be followed by another in the same unconventional style entitled, "The Story of the Solar System; or, The Sun, Planets, and Comets popularly described." I trust, however, that many of my readers will not be content with these mere outlines of a noble science, but will desire to obtain a more complete grasp of the subject in all its bearings by studying first my "Pictorial Astronomy" (Whittaker & Co., 2nd ed.), and then my "Handbook of Astronomy" (Clarendon Press, 4th ed., 3 vols.), which is a comprehensive treatise, yet written in popular language and form so as to subserve the wants of general readers. From both these works thoughts and ideas have no doubt found their way into the present volume.

For the chapter on the work of the Spectroscope in connection with the stars I am indebted to my friend Mr. E. W. Maunder, of the Royal Observatory, Greenwich, one of the highest living authorities on this branch of astronomy.

G. F. C.

NORTHFIELD GRANGE, EAST BOURNE.
December, 1894.

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CHAPTER I.

INTRODUCTORY THOUGHTS.

"By the word of the Lord were the heavens made; and all the host of them by the breath of His mouth."—PSALM xxxiii. 6.

No great while ago a defendant who had to appear at a Court held at Carlisle arrived there true to his time according to the local time at Carlisle appointed by the Court for the sitting; but he found that the Court had met by Greenwich time, and in his absence had decided the case against him. This was considered by certain gentlemen "learned in the law" to be both a hardship and an illegality, and the poor man obtained a second chance of being heard. Subsequently to this incident Parliament passed an Act providing that whenever any expression of time occurs in any Act of Parliament, deed, or other legal instrument, the time referred to shall (unless it is otherwise specifically stated) be held, in the case of Great Britain, to be Greenwich mean time, and in the case of Ireland, to be Dublin mean time.

Quite recently the following incident occurred at Liverpool, the outcome of which, by the way, seems hardly consistent with the statute just referred to. A levy was made by the Sheriff's Order on the household goods of some person

who urged that, as this was done after sunset, it was illegal. The Director of the Liverpool Observatory being called to testify to the time of sunset on the day of the levy, the defendant's objection was upheld. The conclusion appears unavoidable that, in noting the times of sunrise and sunset, local time, and not Greenwich time, must be regarded. This, as I have said above, seems not to be consistent with the statute, but I am not concerned here to discuss the question in that aspect. I only want to use the facts referred to as a means of showing that there is something more in the study of the stars than many persons imagine. In other words, that in inviting my readers to give a little thought to astronomical matters, I am asking them to consider things which are not only not necessarily occult, difficult, or fanciful, but which have in one way or another no slight bearing on business and pleasures of life.

It is not necessary to develope the argument to any great length, but it is just worth a passing thought, in considering the question whether astronomy has any, and if so what, utilitarian value, to remember that those 2 objects of daily interest and use, the almanack and the diary, entirely depend for their existence on the labours of the astronomer in his observatory. In our case, as Englishmen, these books are based on the labours of certain very insufficiently paid members of her Majesty's Civil Service at the Royal Observatory, Greenwich, and at the *Nautical Almanack* office in Gray's Inn Road. Were the staff belonging to either

establishment to resort to the fashionable expedient of a strike for higher pay (and there would be much justification for their doing so), sooner or later all the almanacks and diaries would cease to be published, and the public business of the country would to a large extent come to a standstill. But this is not all. The shipping of England would come to a standstill, or nearly so, and that not figuratively, but literally. Our vessels would have to go back to the principles of navigation practised by the inhabitants of these islands 2000 years ago; they would have to become coasting vessels, feeling their way from place to place, and chiefly by daylight. Long voyages oversea would be well-nigh impossible, or only to be executed in the face of the greatest risks and the wildest chance. Our railway system would become utterly disorganised. A few trains could run, but the intervals between them would have to be considerable, and they could only travel by daylight and at very low speeds.

These general thoughts will, I trust, serve as a sufficient preliminary proof that there is more in the "Story of the Stars" than lies upon the surface of things.

CHAPTER II.

FIRST EXPERIENCES OF A STARLIGHT NIGHT.

Let us suppose a would-be observer of the stars to station himself on some fine evening soon

after sunset in an open and if possible elevated position. A varied and striking, not to say picturesque, spectacle would soon unfold itself to his gaze. Stars invisible during the daytime, because their light was overcome by the superior light of the sun, would soon appear. They would become visible at first only one by one, as it were; then several would seem to start into being, and finally their number would increase, until it might be supposed that many thousands were visible, though in point of actual fact no more than about 3000 stars at the outside can ever be seen by the naked eye at any one time or place.

An attentive scrutiny, prolonged in one case for an hour or two, and in another case for a day or two, will disclose a twofold fact: first, that all the objects assumed to be stars are moving in a body over the face of the sky from hour to hour, whilst two or three brighter ones are to be noticed which not only participate in the constant movement from hour to hour of the whole mass, but have an individual motion of their own in virtue of which either from day to day, or in other cases from week to week, they will be noticed to change their relative positions with respect to the twinkling stars around them. Pausing for a moment to distinguish between these two classes of celestial objects, it may be stated that the bodies which twinkle, and have (seemingly) no *relative* movement, are the "fixed stars," properly so called; whilst the others, it may be only two or three in number on any given even-

ing, and which do not twinkle, are objects of a totally distinct character, and known as "planets."

Taking the sky as a whole, with its 2000 or its 3000 naked-eye stars, the observer (if in a northern latitude) will notice, if he turns his back to the south, remembering where the sun was at mid-day, that after successive intervals, say of a $\frac{1}{4}$ of an hour, new stars are presenting themselves on the right, rising above the horizon. If he will follow some one group in particular far into the night, he will find that it gradually rises in the heavens in the direction from east to west. After a certain interval it ceases to rise higher; then descends on his left, and finally disappears below the western horizon. This onward march is not an attribute of all the stars quite in the simple form thus mentioned, for of some of them it must be said that they do not rise above the horizon nor sink down below it, because they are always above it. Such are the stars which face our observer, who with his back to the south is looking towards the north. Of the stars thus circumstanced there are some which seem to describe a pathway which scrapes, as it were, the northern horizon; whilst others seem to describe circular paths, which become more and more contracted towards a certain star in particular. That star seems almost motionless throughout the entire night, and is known as the "Pole Star." The stars which are, as above stated, always above the horizon, would always be visible during the whole 24 hours

were it not for the sunlight. As a matter of fact, indeed, the larger of them can on any fine day be traced by means of a large telescope round and round during the whole 24 hours day after day throughout the year, weather permitting.

The movement of the heavens which has just been referred to is commonly called the "diurnal movement." A better conception of it perhaps may be had if we imagine (as indeed the ancients did) that we are in the centre of a literal sphere; that the stars are attached to the interior surface of such a sphere; and that it is endued from without with a rotatory motion once in every period of time which we designate a day of 24 hours. Regarding the universe thus, we must, by one more forward stretch of the imagination, consider the heavens to be always revolving around an invisible axis called the axis of the world, which passes through the place of observation and a particular point near to the Pole Star. The direction of motion will be from east to west; and whilst for us in England the visible polar point of this imaginary axis will be the North Pole, the other end of the axis will be pointing in the opposite direction to another point called South Pole. For the reader to obtain a full and true realisation of these statements, which in the abstract no doubt have a visionary sound, he must take a voyage to the Southern hemisphere—say, to the Cape of Good Hope or Australia. Doing this, he will come face to face with a condition of things which at first

sight may be a little puzzling. He will have lost both the North Pole and the Pole Star, and also the constellation of the Great Bear and other constellations which we associate with the north, and will find himself called upon to study a very different situation. In order to discover a polar point he will have to face the south instead of the north; he will find no bright star at, or anywhere near, the South Pole; and no Great Bear to recall the memories of childhood and the nursery.

The remarks in the preceding paragraph will have paved the way for the statement which must now be made, that the study of the stars as regards their location in the heavens is intimately mixed up with terrestrial questions of geography; in other words, that the observer's opportunity of surveying the fields of view afforded by the heavens ever depends upon the latitude (not the longitude) of his place of observation on the earth. Wherever he may be, provided he be not immediately at the equator or pole, he will have to consider the heavens as comprising 3 distinct regions, each with its own particular peculiarities. The first, bounded by an imaginary circle called the "circle of perpetual apparition"; the second, bounded by another imaginary circle called the "circle of perpetual occultation"; the third being all the area not embraced by either of the others. All the stars lying between the first circle and the visible pole will be perpetually visible to our observer throughout the year, barring of course accidents of sunshine or

weather. All the stars lying between the second circle and the opposite (or invisible) pole will be perpetually invisible to our observer, because none of them rise above his horizon. This is the condition of things as regards an observer in the Northern hemisphere. Looked at on the other hand from a station, say in Australia, the converse of the foregoing will be the condition of things. The stars perpetually visible in England will be perpetually invisible in Australia, and the stars perpetually out of view in England will be perpetually in view in Australia.*

The reader will by this time quite understand that when we talk about the celestial sphere, or the vault of heaven, or the axis of the world, or the poles, we are resorting to pure abstractions which are only calculated to convey in a crude fashion ideas of apparent movements which it is difficult to describe in words, or to indicate by pictures, or to reproduce in model with mechanical appliances. It may, however, be said that a pair of globes intelligently studied may be of some service. Perhaps it is worth while to note in passing that ideas and expressions on this subject which we employ simply as figures of speech, were made use of by the astronomers of antiquity in a literal and material sense. Many of them fully believed in the

* The statement in the text will only be absolutely and literally true when the stations between which the comparisons are made are in identical latitudes, the one north and the other south. For instance, it would be about true of Dunedin, New Zealand, and Geneva in Switzerland.

existence of a solid celestial vault with a material axis provided with pivots turning in fixed sockets, the stars being fastened to the surface of the vault by nails or such-like attachments. Vitruvius may be mentioned as one of the best-known writers of antiquity who has recorded as facts ideas of this sort.

It would not be in accordance with the design of this little work to go very deeply into matters of the kind brought under the reader's notice in the pages immediately preceding. Suffice it then to add that whilst the longitude of an observer's position has nothing to do with the question of whether he sees some stars and not others on any given night, it has a good deal to do with the question of what stars are visible at any given moment of time to an American at New York, to an Englishman in London, or to a Hindoo at Calcutta. For instance, when a Londoner is going to bed at the hour of 11 p.m., the New Yorker will be sitting down to his dinner at 6 p.m., whilst the Calcutta Hindoo will be preparing for breakfast. The difference of 11 hours of absolute time which exists between New York and Calcutta will result in each of those places having a totally different batch of constellations presented to its gaze; because London occupies an intermediate position, the Londoner will see certain stars over his head which to the Calcutta Hindoo will appear setting near the W. horizon, and which to the New Yorker will appear low down in the E. horizon, just rising.

Whilst it is intended as far as possible to

exclude from this volume matters of mathematics and geometry, there are a few such matters which must be stated to and be comprehended by the reader if he would follow up, to any good purpose, the study of astronomy as a pleasant and profitable occupation.

We sometimes have to speak of a body being in a "vertical" position. This means "upright," and a heavenly body is in a vertical position when it is exactly over the observer's head. The vertical of a place, then, is the direction from which a body, set free to fall as it will, seems to come when it strikes the earth at the place. It is indicated by the direction of a string made fast at one extremity, whilst the other extremity supports a weight of some kind. Such a combination constitutes a plumb-line, and is used by masons and bricklayers for the express purpose of ensuring the uprightness or verticality of their work. Further, it may be stated that the vertical of a place is constantly perpendicular to the surface of water there which is at rest.

The imaginary point in the sky where the vertical prolonged from the ground upwards meets the celestial vault is the "zenith" of the place of observation. It is of course the point exactly above the observer's head. If one could conceive the vertical prolonged downwards through the earth and coming out on the other side,* and carried forwards till it

* The following "anecdote" illustrates this: An American inquired of as to the suitability of a certain soil for growing carrots, said that they grew so well in it

met the celestial sphere at another point, it would do so at a point which is called the "nadir" of the observer on the upper side, so to speak, of the earth. An observer standing out on an open plain, or better still in a boat on the open sea, will notice that his view of the land in the one case, and of the sea in the other, is cut off from the sky by a circular boundary line, he himself being in the centre of the circle. This circle is called the "horizon." It really is a horizontal plane passing through the place of observation at right angles to the vertical.

The "plane of the meridian" of a place is an imaginary plane passing through what we have spoken of as the axis of the heavens and the vertical of the place. Suitable observation shows that the uppermost and lowermost points in the circles seemingly described by all the stars are situated in this plane. The intersection of this plane of the meridian with the horizon to the north and to the south constitutes what we call the "meridian line," or simply the "meridian" of the place of observation. What it is and what it means will perhaps best be grasped by a consideration of the original meaning of the word. It comes from 2 Latin words, through a single Latin word, the words of origin being *medius* middle, and *dies*, day—meaning in effect the point of the horizon immediately below the place in the

that the roots reached right through to the other side of the earth, when people stole the carrots by pulling them *through* by the *tips*, instead of pulling them *up* (as usually done) by the *tops*.

heavens where the sun is when it has run half its daily course from sunrise to sunset.

With the horizon and the meridian understood, the cardinal points, north, south, east, and west seem to come naturally. An observer placed in the direction mentioned at the beginning of this chapter, that is, facing the Pole Star, will (in England) be facing the North; immediately behind him will be the South; whilst on his right will be the East and on his left the West. These words in English convey very little to us, but in their Latin forms are much more expressive. The Latin, by the way, reappears in the French. For instance, the Latin for "North" is *septentrio*, which recalls the 7 (*septem*) stars near the North Pole; in French it is *septentrion*. Then the South has already been mentioned and reaches us in French as *midi*. Then the East is *oriens* (Fr. *l'orient*), *i.e.*, the place where the sun rises. And the West is *occidens* (Fr. *l'occident*), *i.e.*, the place where the sun falls, *i.e.*, sets.

It is sometimes necessary to consider the position of a star or the distance of one star from another by making a measurement or an estimate along the plane of the horizon, or along some other plane parallel thereto. This is spoken of as a measurement in "azimuth"; or, to put it in another way, let us imagine a plane passing through the zenith and through any star whatever; that would be at the moment of observation the azimuthal plane of the star; and the angle between this plane and the plane of the meridian, or the star's distance from the meridian thus measured, would be the star's "azimuth".

at the particular moment when the observation was made.

A few words respecting angular distances and their measurement seem now needed, but they must be very general because the study of angles is a matter which concerns geometry in the first instance and astronomy only in a secondary sense.

Every circle is considered to be divided into 360 degrees, every degree (°) being subdivided into 60 minutes, and every minute (′) into 60 seconds. Formerly every second (″) was divided into 60 thirds, but this method of counting has become quite obsolete, and when it is necessary, as it often is, to deal with fractions of a second, resort is had to decimals. Occasions, indeed, sometimes arise when it is convenient to go no further than whole minutes and to express as decimals of a minute the seconds which we wish to record. Indeed, on occasions, even the minutes and seconds taken together are set down as simple decimals of a degree. Thus, 45° 12′ 20″ might be expressed as 45° 12′·33 or 45°.205.

The whole circle being taken at 360°, a half-circle embraces 180°; a quarter circle, or "quadrant," is 90°, whilst the eighth, or "octant," represents 45°. An intermediate subdivision, a sixth, or "sextant," furnishes a word which has an astronomical application, but it is to an instrument, and not to the space which the word suggests. The words "octant" and "sextant" as portions of a circle are not in use, notwithstanding that the words themselves exist.

Applying to the circle thus divided the 4 cardinal points already mentioned we obtain

the divisions which constitute the dial of the "mariner's compass," and an attentive consideration of the manner in which that is divided will pave the way for a due comprehension of the manner in which angles are measured for astronomical purposes.

It will be seen by the diagram that if a circle

FIG. 2.—THE POINTS OF THE COMPASS.

is divided into 4 quadrants we are furnished with the 4 principal points, N., E., S., and W. Each quadrant therefore embraces 90° of the 360° which constitute the entire circle. Dividing each quadrant into two halves gives us the subdivisions known as N.E., S.E., S.W., and N.W. Each of these represents the half of 90°, or 45°. Then by subdividing each half-quadrant into half again we obtain what are quarter-quadrants,

though no such phrase is in use. The quarter-quadrants give us the points known as N.N.E., E.N.E., E.S.E., S.S.E., S.S.W., W.S.W., W.N.W., and N.N.W.

We have now got our circle divided into 16 portions each of $22\frac{1}{2}°$. The sailor, however, carries the matter 2 steps further, and by again subdividing into halves the intervals just mentioned he arrives at the 32 "points of the compass," as they are called; then by another subdivision into halves he obtains 64 subdivisions of the circle, though the final appellation is not a "point," but a "half-point."

Speaking generally, the subdivision of the circle for the purpose of steering a ship does not need (except in special cases, of course) any great refinement; that is to say, an order to vary a ship's course by half a point, or about $5\frac{1}{2}°$, is precise enough on the open seas.* But the astronomer in measuring angular distances in the case of the sun and planets, and still more in the case of the stars, has to deal with arcs infinitely smaller than those which the "man at the wheel" is concerned with. Not only arcs as small as 1″, but even fractions of a second have to be taken into account by the use of instruments far larger in size and more finely graduated than the portable instruments, such as sextants and theodolites, used by sailors at sea, and by surveyors on land.

* This remark does not apply to the larger steamers, whether ships of war or belonging to the mercantile marine. These when provided with steam-steering gear are steered to single degrees of the circle.

CHAPTER III

THE BRILLIANCY AND DISTANCES OF THE STARS

The stars are not all equally bright, and custom has divided them into certain classes known as "magnitudes." The largest and brightest are said to be stars of the 1st magnitude; next come stars of the 2nd magnitude, and so on by a descending scale. Stars of about the 6th magnitude are reputed to be the smallest visible to the naked eye, but by the use of telescopes we can go on observing stars down to about the 15th magnitude or even smaller. It will be readily understood that this is a very loose and arbitrary phraseology, but it has become so consecrated by time and custom that it will certainly never be set aside. Whilst everybody is agreed as to what is the brightest star in the heavens, namely Sirius, and that about 20 stars are worthy to be ranked as of the 1st magnitude, though less bright than Sirius, sharp differences of opinion present themselves when we try to mark off 2nd magnitude stars from 1st magnitude stars, and still more when we have to define where the 2nd magnitude stars end and the 3rd magnitude stars begin. Lower down in the scale the difficulties of classification become infinitely greater—they may, indeed, be said to be hopeless.

Considering the love of precision and exactness which characterises nineteenth-century science, it is somewhat singular that so little

has been done to submit to measurement on definite principles the brilliancy of the various stars, at any rate those visible to the naked eye. Sir John Herschel made an attempt in this direction about 60 years ago. Many years afterwards some Germans, especially an observer named Seidel, nibbled at it, but Professor Pickering in America and the late Professor Pritchard of Oxford, working at Oxford and in Egypt, are the only two observers who have accomplished any results worthy of the subject on a well-organised basis. Pickering's labours at Harvard College Observatory, Boston, U.S., have been published in the form of a catalogue of 4260 stars, whose magnitudes have been determined instrumentally on definite and intelligible optical principles. Pritchard's catalogue comprises fewer stars than Pickering's, but like its American rival is based upon philosophical principles, an instrument called the Wedge Photometer having been employed. Both catalogues labour under the disadvantage, that having been made in the Northern hemisphere they do not include the whole area of the heavens.

Taking the stars as we find them, a very slight amount of attention will show that not only are they of different degrees of brilliancy, but that they are of different colours More prolonged and refined study will disclose the further facts that some of them vary both in brilliancy and in colour. These matters are of such extreme interest that it will be best to devote a special chapter to them. The brighter stars are distinguished from one another in

various ways, and many of them received in bygone times quaint and curious names. At a very remote period they were grouped into constellations, most of which survive to the present time and are recognised to be of use to a certain extent.

Leaving the constellations for treatment in a separate chapter, and confining our attention for the moment to the stars as individual objects, it may be remarked that in order to distinguish one star from another the ancient astronomers often indicated a star by speaking of the position it occupied in the constellation to which it belonged. Thus Aldebaran was called *Oculus Tauri*, "the Eye of the Bull." This custom was followed and largely developed by the Arabians, and many of the names invented by them are still in use, corrupted or transformed. A German astronomer named Bayer was the first to attempt (about 1603) on any considerable scale to simplify, and so improve the old plan, but the Arabian names had, either in their Arabian form, or as translated into Latin, taken such deep root that many of them are even still in constant use. Bayer's plan was to attach to the prominent stars of each constellation the letters of the Greek alphabet, though the popular idea that the opening letters of the alphabet were reserved for the brightest stars and the later letters for the less conspicuous stars, is unfortunately not universally true. However the Greek letters α, β, and γ, do indicate often the 3 brightest stars of a constellation. Bayer's letters are still in vogue, the name of the con-

stellation being put after each in the genitive case. Thus the star which bears the name of Sirius is termed α Canis Majoris, Arcturus is α Boötis, and so on. The Persians are said to have considered 3000 years ago that the whole heavens were divided into 4 great districts, each watched over by a "Royal" star. The 4 stars, each very brilliant and remarkable, which occupied the important positions of "guardians" of these districts were Aldebaran in Taurus, Antares in Scorpio, Regulus in Leo, and Fomalhaut in Piscis Australis, but Arago, who mentions this tradition, can hardly be deemed accurate in his remark that the 4 stars in question divide the heavens into 4 almost equal portions.

This chapter may be conveniently brought to a close with a list in the order of brightness of the stars which are commonly ranked as of the 1st magnitude:—

1. α Canis Majoris (*Sirius*).
2. α Argûs (*Canopus*). Invisible in England.
3. α Centauri. Invisible in England.
4. α Boötis (*Arcturus*).
5. β Orionis (*Rigel*).
6. α Aurigæ (*Capella*).
7. α Lyræ (*Vega*).
8. α Canis Minoris (*Procyon*).
9. α Orionis (*Betelgueze*).
10. α Eridani (*Achernar*). Invisible in England.
11. α Tauri (*Aldebaran*).
12. β Centauri. Invisible in England.
13. α Crucis. Invisible in England.
14. α Scorpii (*Antares*).
15. α Aquilæ (*Altair*).
16. α Virginis (*Spica*).
17. α Piscis Australis (*Fomalhaut*).

18. β Crucis. Invisible in England.
19. β Geminorum (*Pollux*).
20. α Leonis (*Regulus*).
21 α Cygni (*Deneb*).

With respect to the first 13 of the above stars it may be said that there is not much difference of opinion as to their relative rank (though some authorities do make Vega and Capella change places), but as to the remaining 7 there is not the same accord, some ranking Altair and Spica before Antares, and Regulus before Fomalhaut, Pollux, and β Crucis These stars are pretty evenly distributed between the Northern and Southern hemispheres, for 10 are Northern and 11 Southern

The following are the approximate dates on which such of the foregoing stars as are visible in England come to the meridian at midnight:—

Procyon	... January 14	Deneb	... July 31
Pollux	... January 15	Fomalhaut	. . September 3
Regulus	... February 21	Aldebaran	... November 28
Spica	... April 11	Capella	... December 8
Arcturus	... April 24	Rigel	.. December 8
Antares	... May 27	Betelgueze	.. December 18
Vega	... June 29	Sirius	... December 31
Altair	... July 18		

Not entirely foreign to the question of the brilliancy of the stars is the question of their distance. At the first blush of the thing an uninformed reader might naturally say that to measure the distance of a star from the earth is impossible. But so far as the principle of this task is concerned the problem is an easy one. It is in the practical working out of the prin-

ciple that the difficulty lies; and this again rather arises from the extreme delicacy of the measurements and necessary safeguards than from any other cause. The process merely involves the taking of certain angular measurements and applying to them certain familiar theorems of trigonometry. It differs scarcely at all from analogous operations which are carried out every day on the earth by those engaged in land surveying. What is involved will perhaps be understood by considering what happens when a person enters a large park at one end, intending to cross to the far side where there are a number of trees in an avenue, passing *en route* 2 or 3 trees in the open. The trees in the far-off avenue seem to be at no great distance apart, and the trunk of one of them is nearly hidden by the trunk of one in the middle of the park; but soon after the pedestrian has started (perhaps when he has got over 50 yards) he notices that the 2 last-named trees, which a minute or two ago seemed almost in contact, are evidently some distance apart, and after walking for perhaps another minute (say another 50 yards) he sees cause to infer that a space of perhaps 120 yards separates the trees which, before he got in motion, appeared almost to touch. This transformation is the effect of "parallax," and the apparent displacement of the trees is due to the real displacement of the observer, owing to his having used his legs. But supposing the 2 trees singled out as above, instead of being within the same park close at hand had been 2 miles off, an advance of 50 yards would have

caused so trifling a displacement that, though a telescope provided with a micrometer would have detected it, the naked eye might not have done so. Why this? Because in the first case the distance traversed (50 yards) was a large fraction of the distance (say 400 yards) at which the trees were situated from the starting-point (as 50 : 400 : : 1 : 8). But in the second supposed case the distance traversed (50 yards) was but a small fraction of the whole distance (say 4000 yards) separating the pedestrian from the trees. The proportion is now to be expressed thus:—As 50 : 4000 : : 1 : 80.

Let us apply these similes to the stars. An observer on January 1st is using his telescope when the earth is at a certain known point in its annual orbit round the sun. He determines the position of a certain star. He waits 6 months, and then, on July 1st, again determines the place of his selected star; he finds it occupies the same place. He is on July 1st removed by twice the radius of the earth's orbit, or 186 millions of miles, from the place he occupied on January 1st. If, notwithstanding this enormous displacement of himself, the star seems to have undergone no displacement, our observer argues that the star must be so far off that 186 millions of miles is a fractional part of its distance, too small to be appreciable, just as the 50 yards mentioned above is only a small fractional part of 4000 yards.

The principle of all this has been applied to several hundred stars, but only about 2 dozen have yielded positive results. These results, so

far as they go, seem to tell us that the nearest star of those experimented upon is α Centauri, and that the 4 next nearest are 61 Cygni, 21185 Lalande Ursæ Majoris, Sirius, and μ Cassiopeiæ.

Such standards as miles, or even millions of miles, are quite unmanageable in dealing with distances such as those which separate the nearest stars from the earth, so it is customary to employ as the unit of stellar distances the distance traversed by light in one year. Now light travels at the rate of about 185,000 miles in one second, or about 63,000 times the earth's distance from the sun in one year. Applying these figures to the circumstances of α Centauri, we find that as the parallax of that star is only about $\frac{3}{4}$ of a second of arc, a ray of light from it would not reach the earth in less than $4\frac{1}{4}$ years. This distance expressed in miles amounts to 24,750,000,000,000; and α Centauri is, so far as is known, *the nearest star!* The reader will hardly require any further explanation of the statement made above that a mile is a hopelessly ineffective and inadequate unit in which to express stellar distances. It only remains to add that it is doubtful whether any of the stellar parallaxes hitherto arrived at are accurate to within $\frac{1}{50}$ of a second of arc. Now $\frac{1}{50}$ of a second is the angle subtended by $\frac{1}{16}$ of an inch at a distance of 10 miles! Observations of stellar parallax, therefore, need very first-class instruments and men, and it is on this account that the results up to the present time are neither very numerous nor particularly consistent.

CHAPTER IV.

THE GROUPING OF THE STARS INTO CONSTELLATIONS.

THE visible stars are commonly treated as arranged in groups which are called "constellations." The circumstances under which this grouping was brought about involve so many interesting historical points that the history of the constellations may well form a separate chapter. Let me then limit the present chapter to a few general hints and remarks on the finding of the constellations.

A reader who wishes to be able to do this with facility must enter upon the study of the stars methodically, and in accordance with a definite plan, and must be prepared to persevere with his work at regular and not very long intervals of time through an entire period of 12 months. In making this suggestion I lay a good deal of stress on the work being done systematically, and without any considerable gaps of time in the doing of it. The importance of this will be understood when it is borne in mind that a given star comes to the meridian every night 4 minutes sooner than it did on the preceding night. This has the effect in the course of a fortnight of displacing a star by 15° of arc, the time of observation remaining the same. In other words, if an observer wishes to see a given star on the meridian a fortnight after his first observation of it, he must take post at his telescope (sup-

posing he is using one which only works up and down in the meridian) one hour earlier in the evening than the hour at which the first observation was made. It would soon be seen in practice why there was not only no advantage in thus altering one's times but a positive disadvantage. The ordinary object of a professed student would be, not to have a constant change in the hours of his occupation, but to have a constant change in the occupation itself; that is, in the stars he is wishing to learn the names of, the hours of work remaining (for his personal convenience) probably much the same, say 9 p.m. to midnight.

There is another and also cogent reason for keeping at this work regularly and avoiding long breaks. Though the stars maintain, so far as they themselves are concerned, speaking generally, the same relative positions throughout the year, yet it makes a good deal of difference to the unpractised eye in the identification of particular stars whether they are looked at whilst they are in the neutral position (as it may be called) of the meridian, or when they are oblique to the meridian, eastwards of it and rising, or westwards of it and setting. These differences can only be properly appreciated by being considered experimentally on a starlight night in the open air, for no verbal account of them can be adequate.

A tourist who is travelling through a hilly country, unless he is a professional land surveyor employed on professional work, does not go through the formality of marking off his meridian

line and of setting out by an instrument the bearings of particular peaks and towers for the purpose of getting a record of them on paper. As a mere traveller for pleasure he will probably have with him nothing more than a map and a pocket compass; and his aim will be only to identify particular mountain-tops, church towers, villages, or other objects of special interest. There is only one way in which he will attempt to proceed. Assuring himself by means of his guide-book or map, or by the aid of local information, of some one, two or three prominent objects, the identity of which evidently admits of no doubt, he will then feel his way by eye first from one point and then from another point, constantly consulting his map and compass. By some such process as this, after starting with two or three objects recognised to a certainty, he will be able to learn the names of all the places within sight which he wishes to identify, to the number it may be of several dozen.

This mode of procedure may be commended to the would-be student of the Starry Heavens. Such an one should obtain practice for his work by making sure at starting of the names of two or three prominent stars. He should then feel his way in between them by fixing in his mind, one after another, minor triangles of stars, comparing every one with his map as he goes along, taking particular care not to proceed with the identification of a second triangle until he has quite satisfied himself that he has accurately identified the stars forming the first.

It has already been mentioned that the practice has long prevailed of designating the more conspicuous stars in every constellation by the letters of the Greek alphabet. An adequate knowledge of the small letters of this alphabet is therefore an indispensable accomplishment for every student of the starry heavens. These letters are :—

α	Alpha.	ν	Nu.
β	Beta.	ξ	Xi.
γ	Gamma.	o	O-mīcron.
δ	Delta.	π	Pi.
ϵ	Eposilon.	ρ	Rho.
ζ	Zeta.	σ	Sigma.
η	Eta.	τ	Tau.
θ	Theta.	υ	Upsīlon.
ι	Iota.	ϕ	Phi.
κ	Kappa.	χ	Chi.
λ	Lambda.	ψ	Psi.
μ	Mu.	ω	Omega.

I will now endeavour to apply the foregoing ideas to the study of the stars, starting with the Great Bear as being the most conspicuous of those constellations which never set in the latitude of London. The tail and hind-quarters consist of 7 brilliant stars. Four of these (α, β, γ, δ) have long been likened to a wain or waggon, the other 3 (ϵ, ζ, η) being fancifully called the horses; the 7 taken together making "Charles's Wain" or the "Plough"—to mention some old English designations. The hind wheels or the 2 stars (β, α) farthest from the horses are called the "Pointers," because they point towards the Pole Star (α Ursæ Minoris) at

the tip of the Little Bear's tail. A line carried from the Pointers beyond the Pole Star leads to Cepheus and Cassiopeia—constellations abutting on the Milky Way where it comes nearest to the Pole. Cassiopeia comprises several prominent stars which form a group resembling the letter W or the letter M, according to the time

FIG. 3.—URSA MAJOR AND POLARIS.

of year at which they are viewed. The 2 northernmost wheels of the waggon (δ, α, Ursæ Majoris) point to the bright star Capella in Auriga, which is also circumpolar in British latitudes. The stars of the Great Bear may be advantageously employed by the student as an approximate scale of angular distances in making estimates of the distances between star and star. Thus:—The Pointer (α) nearest to the Pole is

$28\frac{3}{4}°$ from it; from β to γ is 8°; from ζ to η is 7°; from δ to ϵ is $5\frac{1}{2}°$; from α to β is 5°; from γ to δ and from ϵ to ζ is in both cases $4\frac{1}{2}°$.

Descending diagonally along the Milky Way from Cassiopeia towards Capella (α Aurigæ) we come to α Persei, and a little farther from the Pole we find Algol (β Persei), a celebrated variable star in Medusa's head. If we carry our eyes across the Milky Way in the opposite direction we arrive at Deneb, the brightest star (α) of Cygnus (the Swan); and beyond Cygnus, a little out of the Milky Way, is Vega, the brightest star (α) in Lyra (the Lyre). Draco (the Dragon) consists of a long winding chain of stars running partly round Ursa Minor (the Little Bear). In the space bounded by Cassiopeia, Cygnus, and Draco, lies the constellation Cepheus.

Near Algenib (γ Pegasi) and pointing directly towards it are 2 conspicuous stars of Andromeda (α, β), whilst a 3rd (γ) lies a little beyond them. Andromeda will always be readily known by reason of the connection of the bright star (α) in her head with the large trapezium of Pegasus (α, β, γ), the 4 stars forming the well-known "Square of Pegasus."

An imaginary line projected through the Great Bear and Capella passes to the "Pleiades," the celebrated group in Taurus (the Bull), of which we shall have more to say hereafter (in Chap. XIV. *post*), and then turning at a right angle reaches Aldebaran (α Tauri, *alias* the "Bull's-eye") and the shoulders (α, γ) of Orion. Orion is to the naked eye by far the most magnificent

of all the constellations, whilst it is peculiarly rich in telescopic objects. Orion may always be identified by the 3 bright stars in its "Belt," which occupies the middle of a large quadrangle of still brighter stars. Aldebaran is a reddish star, the most prominent of the "Hyades," a cluster resembling the letter V, and not far from the Pleiades. Aldebaran, the Pleiades, and Algol (β Persei) make the upper, while Menkab (α Ceti), in the Whale's jaw, with Aries, make the lower points of a large W. The head of Aries (the Ram) is indicated by two principal stars (α, β), the latter of which has a small attendant.

An imaginary line drawn from the Pole Star and carried midway between the Great Bear and Capella (α Aurigæ) passes to Castor and Pollux (α, β Geminorum), two well-known stars in the heads of Gemini the Twins; whilst forwards to the S. of Gemini it will meet Procyon (α Canis Minoris) the brightest star of the Lesser Dog. From thence by bending the line across the Milky Way and carrying it as far again it will reach Sirius (α Canis Majoris) in the Greater Dog's mouth, and will then pass to a somewhat conspicuous star, which in England is quite in the southern horizon, Columbæ, 33° S. of the middle star in Orion's belt.

Algol (β Persei) and Castor point to Regulus (α Leonis, *alias* Cor Leonis, the "Lion's heart") which is situated at one end of an arc with Denebola (β Leonis), the tuft of the Lion's tail at the other end. S. of Regulus and preceding it, *i.e.*, coming to the meridian before it by about

$\frac{3}{4}$ hour, is Cor Hydræ (α), the space between them being occupied by the modern and insignificant constellation of the Sextant.

The Pole Star and the middle horse of the waggon (ζ) direct us to Spica, the brightest star (α) of Virgo, considerably distant, whilst forwards, towards the horizon, we shall reach Centaurus. The Pole Star and the first horse (η Ursæ Majoris) conduct us nearly upon Arcturus in Boötes (α), by which fine star, with Spica (α Virginis) and Regulus (α Leonis), a splendid triangle is formed. Following at a distance to the southward is Antares (α Scorpii), "the Rival of Mars," which with Arcturus and Spica constitute another large triangle, having within it the two bright stars, α and β Libræ.

Corona Borealis, the Northern Crown, is nearly in a line between Vega (α Lyræ) and Arcturus (α Boötis); and the heads of Hercules and Ophiuchus lie between Lyra and Scorpio. In the Milky Way, below the part nearest to Lyra and on a line drawn from Arcturus through the head of Hercules, is the bright star Altair in the Eagle (α Aquilæ), which makes with Vega and Deneb (α Cygni) a conspicuous triangle. Closely following Aquila is a remarkable group of stars forming the constellation Delphinus, the Dolphin.

The last and brightest (α) of the 3 principal stars in Andromeda makes with 3 stars of Pegasus (α, β, γ) the large "Square" or trapezium already mentioned, of which the side formed by β and α points to Fomalhaut (α Piscis Australis),

situated in the mouth of the Southern Fish, between the tails of Cetus and Capricornus.

The line of the ecliptic may without difficulty be traced by the observer when his eye becomes familiar with the stars now about to be enumerated. Not far from the Pleiades are the Hyades with Aldebaran (α Tauri), a little S. of the ecliptic. To the N.W. of Aldebaran at some distance is the chief star of Aries (α); while to the N.E. of that star are Castor and Pollux (α and β Geminorum). Regulus (α Leonis) is on the line of the ecliptic; and Spica (α Virginis) is but a very little to the S. of it. A start being thus made with the ecliptic, the zodiacal constellations will be easily distinguished in their order from W. to E. as follows:—Aries lies immediately between Andromeda on the N. and Cetus on the S., the three asterisms reaching nearly from the horizon to the zenith; Taurus will be recognised by the Pleiades, Aldebaran (α) and the Hyades; Gemini, the highest of the signs as seen in the Northern hemisphere, by Castor and Pollux (α and β); Cancer, by the historic group Præsepe, in the midst of a waste rather void of stars; Leo by the stars Regulus (α) and Denebola (β); Virgo, by Spica (α) to the S. of Coma Berenices; Libra in mid-distance between Virgo and the next constellation Scorpio; Scorpio, by the red star Antares (α) and its 3 other very conspicuous stars (β, δ, π); Sagittarius as being the lowest (*i.e.*, most southerly) of all the signs; Capricornus S. of the Dolphin; Aquarius under the neck of Pegasus: and the Pisces between Pegasus, Andromeda, and Cetus. The following

familiar lines, though they do not rise to a high standard of "poetry," are nevertheless very convenient as an aid to the memory :—

The *Ram*, the *Bull*, the heavenly *Twins*,
And next the *Crab*, the *Lion*, shines.
The *Virgin*, and the *Scales* ;
The *Scorpion*, *Archer*, and *Sea-goat*,
The Man that holds the *water-pot*,
And ***Fish*** with glitt'ring tails.

The account just completed of what may be called a "personally conducted" tour of the heavens, is at the best a hasty and superficial performance, and I hope that the bulk of my readers who have accompanied me thus far will aspire to something higher and more exact, even though there may be involved some details, the mastery of which will require a certain amount of effort and application.

A full list of the several constellations arranged in the order in which they come to the meridian, that is to say in the order of their Right Ascensions, will be found in the Appendix ; but it is necessary to explain here what the term "Right Ascension" means, and also what another and allied term "Declination" means. Perhaps this will be easiest done by means of a terrestrial analogy.

Everybody, I suppose, knows that Khartoum, the scene of a grievous tragedy, is in Africa. But how many of my readers could open an atlas, turn to the map of Africa, and go straight with his finger-tip to the city of Khartoum? But if he knew beforehand that Khartoum was

situated in latitude 15° 35′ N. and longitude 32° 30′ E. of Greenwich, the finding of it would be an easy matter, promptly accomplished by the aid of a network of lines running up and down and across the face of the map. Now what latitude and longitude are for terrestrial geography, declination and right ascension are for celestial geography (so to speak), only just a little different.

It is not difficult to make clear what declination is, but an explanation of right ascension will not be taken in so readily. We have already seen that the whole visible sky is to be regarded as in some sense a sphere, with us, on the earth, apparently as its centre; and that the aforesaid sphere turns on an imaginary axis directed to 2 poles. Midway between the 2 poles lies the equator, and as it is a semi-circle (or 180°) from pole to pole the polar distance of the celestial equator (which is the earth's equator prolonged to the heavens) will be 90°. For some purposes it is occasionally the practice of astronomers to count angular distances from the N. pole towards the equator, but the regular and ordinary practice is to count from the equator to the poles, N. or S., as the case may be. Hence we obtain the expressions "north declination" and "south declination," as applied to the places of the stars, and these expressions are, in a certain sense, the counterpart of the expressions "north latitude" and "south latitude" used with reference to places on the earth.

The term "right ascension" is not to be brought home to the mind quite so easily. In

the case of terrestrial longitudes there is no difficulty in finding a definite and immovable terminus to start from. Many European nations are using the meridian of Greenwich for this purpose, though Frenchmen count from Paris, Germans from Berlin, and so on. But in the case of the stars a fixed zero is not so easy to find and still less easy to keep. However, astronomers have long been agreed to make what is called the "First point of Aries," *alias* the "Vernal Equinox," their starting-point for right ascensions. This is the point where the sun, in the course of its annual journey through the signs of the zodiac, crosses the equator, going from south to north, in the month of March on the 20th day of that month. The phrase "vernal equinox" means the moment of equal day and equal night in the spring.* It is also at this moment that the clocks used by astronomers in their observatories read 0h. 0m. 0s. Owing to the operation of disturbing causes, the nature and description of which do not belong to this chapter, or indeed to this volume, this point is incessantly shifting in the heavens. By virtue of a change called the "precession of the equinoxes," the actual place of the equinox goes backwards about 50″ every year, and this is what I meant by saying above that the zero for celestial longitudes is not only not easy to find but when found cannot readily be kept. It must suffice, then, for my present purpose to remark that if we wish to fix the right ascension of a star we must imagine a meridian to pass through

* Lat. *ver*, spring; *æquus*, equal; *nox*, night.

it; then imagine a meridian to pass through the vernal equinox and note the angle which the former meridian makes with the latter measured in degrees of arc along the equator from W. to E. That angle will be the star's R.A. It may be expressed either in degrees, minutes, and seconds of arc (° ′ ″), or in hours, minutes, and seconds of time (h. m. s.). The latter method is now universally employed, the former having been discarded.

The relation of arc to time in connection with the measurement of angles of right ascension will be readily remembered by noting that a minute or second of *time* represents a space of 15 times the corresponding denomination in *arc*, while the hour is 15 times one degree, that is 15°. The minute and second of time are denoted by the initial letter of their names, whilst the minute and second of arc are denoted by special symbols. Thus we arrive at the following little table which the reader should get clearly fixed on his mind:—

$1^h = 15°$	$1° = 4^m$
$1^m = 15'$	$1' = 4^s$
$1^s = 15''$	$1'' = 0{\cdot}066^s$

Perhaps this is as good a place as any at which to warn the reader against a trap which he is very apt to fall into. The "signs of the zodiac" are not the same as the "constellations of the zodiac" (more often spoken of as the zodiacal constellations). Twenty centuries or so ago the astronomers of antiquity, with the 12 zodiacal constellations within their know-

ledge, got into the natural and not inconvenient habit of talking of the sun in its apparent annual journey through the heavens along the ecliptic as passing successively into and out of the several signs of the zodiac. Each of these signs was regarded as occupied by a constellation from which it took its particular name. Commencing at the vernal equinox the first 30° through which the sun passed, or the region of stars in which the sun was located during the month following, was called the sign Aries. The second 30° was called the sign Taurus, and so on through the 12 signs, which are identical in name and follow in the same order as the existing 12 zodiacal constellations. Although there are still 12 signs and 12 constellations, sign and constellation no longer correspond. Though the sun when it crosses the equator in the month of March enters the *sign* Aries, it does not reach the *constellation* Aries till nearly a month later. This discrepancy is due to the yearly accumulations of 50″ each which have been going on during the 20 centuries mentioned and which are connected with the phenomenon of the precession of the equinoxes already briefly alluded to.

These preliminary explanations will suffice to enable the reader now to settle down seriously to a study of the constellations. This task must be carried out on starlight nights with the aid of a good star-atlas* and a bull's-eye lantern,

* I have found no English one as good as Keith Johnston's, edited by Hind: and this because the stars show as white on a deep blue background. Klein's, published by S.P.C.K., is also cheap and very good.

assisted or not, as may be convenient, by an opera-glass. In the Appendix will be found a Table of the constellations, omitting a few insignificant modern ones not generally recognised by astronomers.

CHAPTER V.

THE HISTORY OF THE CONSTELLATIONS.

To the grouping of the stars into constellations may well be applied the legal phrase that the custom is so ancient that the memory of man runneth not to the contrary. The germs of it are evidently to be found in Holy Scripture. The three following passages, which I cite from the Revised Version, whatever else may be said of them, clearly imply that the allusions are to some well-established usage :—

> "Which maketh the Bear, Orion, and the Pleiades, and the chambers of the south." (Job ix. 9).
>
> "Canst thou bind the cluster of the Pleiades,
> or loose the bands of Orion? Canst thou lead
> forth the Mazzaroth in their season? Or
> canst thou guide the Bear with her train?"
> (Job xxxviii. 31–2).
>
> "Seek Him that maketh the Pleiades * and Orion."
> (Amos v. 8).

The constellations now in use are about 80 or 90 in number, counting a few minor

* The Authorised Version has here "The Seven Stars."

ones devised during the last century, chiefly for the Southern hemisphere, but by no means counting all that have been proposed. It has been well remarked :—"Half a century ago no astronomer seemed comfortable in his position till he had ornamented some little cluster of stars of his own picking with a name of his own making." Of the constellations now recognised, no fewer than 48, and those including with scarcely any exception the largest and best known, are recorded by Ptolemy, and therefore have an unchallenged antiquity of 2000 years, yet the date of the actual invention of even one of them is quite unknown. Seneca attributed the subdivision of the heavens into constellations to the Greeks 1400 years before Christ, but there is no proof of this, and if it is permissible to draw inferences without having many facts to go upon (a common practice nowadays), I should be rather inclined to give some of the credit of inventing the constellations to the Chaldæans or Egyptians, or to both of them in shares, the Egyptians having developed that which they derived from the Chaldæans, as the Chaldæans may have developed something they derived from peoples which preceded them. Some writers, indeed, have thought that a much greater antiquity should be assigned to the constellations, and there are not wanting traces of proof to support this idea. Neglecting for the moment the ancient constellations as a whole, it certainly seems clear that a special degree of antiquity attaches to the signs of the zodiac, and no wonder, seeing that they remind

us, amongst other things, of the apparent annual path of the sun amongst the stars.

It seems more than probable—almost certain—that the word "Mazzaroth" quoted above from Job xxxviii. 32, and left untranslated in the text by the authors of the Revised Version, means what they have suggested in the margin, namely, the circle of the zodiac. And it is quite consistent with this to find, as a modern writer has pointed out, that:—"These signs were known among all nations and in all ages. From the almost antediluvian chronologies of China, India, and Egypt, to the traditions of the recently discovered islands of the South Sea, traces of them are discovered most clearly among the most ancient and earliest civilised nations. In the remains of Assyria they are recognised; in those of Egypt they are perfectly preserved; in those of Etruria and Mexico they are traceable. This wide diffusion indicates a common origin, both of the race of man and of the symbols of astronomy. The love of symbols has been considered as natural to man; the creation amid which he is placed is symbolical. Of this universal tendency the inventors of astronomy seem to have availed themselves, rendering it subservient to man's spiritual education by familiarising to his mind the lofty truths of Divine revelation."

"The earliest positive evidence of the primeval existence of the signs is in the Chinese Annals, where it is said that the Emperor Yao, 2357 years before the Christian era, divided the 12 signs of the zodiac by the 28 mansions of the

moon; but it is not said that he invented them. The Chinese national emblem of the dragon appears to be the dragon of the sphere, which was at that time the polar constellation, the brightest star in the dragon's head having been the Pole Star in the antediluvian ages. The Egyptians, on whose early monuments the signs are found, acknowledged that they derived their astronomy from the Chaldæans. The Chaldæans attributed their science to Oannes, supposed to be Noah. The Arabs and Brahmins, among whom astronomy was early cultivated, seem to have derived it from Abraham, through Ishmael, and the children of Keturah. The Greeks supposed their imperfect knowledge of the subject came through the Egyptians and Chaldæans. The Romans are thought to have received through the Etrurians the names of the signs still in use among European nations. The Etrurians are considered to have derived them, with their other arts and sciences, from Assyria. The early Greek poet Hesiod is said to have made use of Assyrian records. He mentions some of the constellations by the names they now bear. Cleostratus [*circa* 500 B.C.] was acquainted with the signs, and wrote on Aries and Sagittarius. A later Greek poet, Aratus, described the constellations such as we now have them, and by equivalent names. He gave neither history nor conjecture as to their date, their meaning, or their origin. They were to him, as to us, of immemorial antiquity."

The thoughts unfolded in the foregoing extract are of great interest, but it is obvious that

a thorough investigation of this subject would lead us far beyond the limits of this little volume.

CHAPTER VI.

THE NUMBER OF THE STARS.

To say much that is definite about the number of the stars is in one sense a very difficult thing to do if the idea is to furnish any trustworthy or adequate information on the subject. The words of Holy Scripture, "Look now towards heaven, and tell the stars, if thou be able to number them," * cover much more than appears at first sight. To say that the stars are innumerable is far from being a mere poetic

FIG. 4.—ORION.

phrase; it is indeed no more than a prosaic matter of fact. Nevertheless it may probably

* Genesis xv. 5.

surprise some persons to be told that according to the estimate of the distinguished German astronomer Argelander the number of stars visible to the naked eye in the latitude of Berlin is only 3256, and must be put no higher than about 5000 in all for the whole heavens. The number to be seen becomes greater as we approach the equator from the middle latitudes of either hemisphere, owing to the wider expanse opened up to an observer stationed at the equator. An observer located in a place the latitude of which is 0° will see in the course of the year *all* the naked-eye stars in the heavens.

Argelander's totals arranged in magnitudes are as follows:—

			Stars.
1st magnitude		=	20
2nd	,,	=	65
3rd	,,	=	190
4th	,,	=	425
5th	,,	=	1100
6th	,,	=	3200
7th	,,	=	13,000
8th	,,	=	40,000
9th	,,	=	142,000

This matter has been made the subject of estimate by various observers, including especially the late Professor Grant of Glasgow and Karl Von Littrow of Vienna. Their figures, though fairly accordant as regards naked-eye stars in the aggregate, differ a good deal, magnitude by magnitude, owing to there being no recognised defined standards of magnitude.

As to this, however, it may be remarked as

a thing by the way, that Seidel, a German observer who has given much attention to the matter, has suggested the following as standard stars for the first 4 magnitudes :—

1st—α Aquilæ, α Virginis, α Orionis.
2nd—α Ursæ Majoris, γ Cassiopeiæ, Algol (at max.).
3rd—γ Lyræ, δ Herculis, θ Aquilæ.
4th—ρ Herculis, λ Draconis (too bright), μ Boötis, θ Herculis (too faint).

It may be well to point out that the statistics just given, though necessarily somewhat approximate, are not to be regarded as imaginary, though of course to count a number of points of light like stars is not in itself an easy task. It may be worth while, therefore, to carry the foregoing statements a little farther. A very painstaking astronomer, also a German, Heis of Münster, affirmed that it was not possible to count more than about 5000 stars visible in the sky available in Central Europe. Endowed with a sharp sight, and adopting various artifices (such as shutting out all artificial light and marking off by means of a great black tube each region of the sky under examination), he found himself able at Münster to see 5421 stars. Inasmuch as he could from that one place in the course of a year examine in succession $\frac{8}{10}$ths of the heavens, he concluded that supposing the portion of the Southern hemisphere which he could not see resembled in a sense the rest of the sky which he could see, the sum total of the stars visible to the naked eye would mount up to about 6800. But it deserves notice that no possible

number of stars which could be counted would represent the stars which an eye could discern. The eye can take notice of more than it can count, because when any given star imprints itself upon the centre of the retina, others whose images fall upon the corners of the eye, so to speak, seem to vanish. This is a point as to which appearances are apt to be very deceptive. It may be well here to remark that it is important to distinguish clearly in the mind between the results of a single gaze at the sky, the eye being for the while fixed, and a look all round. In the former case it may be taken that no more than a space of 13° or 14° can be taken in simultaneously, whilst by moving the eye methodically in successive directions the whole expanse of the heavens may be brought under review.

Secchi noted the following experiment as one that he often tried with interesting results. After taking a glance at some particular part of the heavens he would transfer his eye to the finder of the great telescope at the Roman College at Rome, and would see in this subordinate telescope, whose field was no larger than $\frac{1}{2}$°, as many stars as were to be seen in the 13° or 14° grasped by the naked eye. Passing then to his great telescope, armed with an eye-piece showing only an arc of 15′, or one-fourth the area of the field of his finder, he would still see as many stars as in the finder; proceeding yet further to diminish the field by increasing the power, the number of the stars would scarcely diminish, because, though the area was cur-

tailed, yet the increased magnifying power revealed minute stars which had previously escaped notice. Thus it came about that in certain localities it was possible to see in a field no more than $\frac{1}{12}°$ in diameter as many stars as were visible to the naked eye in a field 13° in diameter. This train of thought will readily enable the general reader to realise the fact that the larger our telescopes become the more stars we can discern; in other words, that as we cannot say for a certainty how large our telescopes might become, so accordingly we cannot say when stars hitherto unseen will cease to be invisible by becoming visible. So that we may indeed say with Galileo that the stars are *innumerable.*

The heavens are not everywhere equally rich; in many places even with the largest instruments one can find in a field of $\frac{1}{4}°$ scarcely 5 or 6 stars; it would not, therefore, do to judge of the number of the stars by these exceptional regions. An effort was made by the two Herschels, Sir William in the Northern hemisphere, and Sir John in the Southern hemisphere, to ascertain the possible number of the stars. It is easy to understand that this is one of the most gigantic tasks which an astronomer could undertake, because it could never be completed in the lifetime of one man. Sir W. Herschel adopted an indirect method to arrive at his results. Making use of his 20-ft. reflector, he directed it successively towards certain parts of the heavens, chosen in irregular order, of which he noted the right ascension and declination.

These regions were so distributed over the heavens as in a way to result in the sky being dotted over with a network of surveying stations equi-distant from each other. The field of his telescope was just $\frac{1}{4}°$, and the magnifying power 120. He counted in each field the number of stars visible in it; in particular places where the number was so great as to render counting impossible he made an estimate. Having gathered together a certain number of these counts, or estimates, in a particular part of the sky, he summed up the total number of stars seen, and divided this total by the number of the groups. The resulting figure was taken to represent the mean average density of the stars in the neighbourhood of the place examined. This method, the only one possible in practice, has some defects; still, employed on the large scale carried out by Sir William Herschel, it gave results so far conclusive that no more modern effort has yet superseded it. Of course it will often happen that a certain locality will be very rich in stars, whilst in another like area, not far off, there will be a great scarcity of stars; still, taking rich and poor neighbourhoods together, a fairly trustworthy average result will be obtained. It has already been stated that to take a census of the whole heavens would be a work so vast that no one man could ever hope to accomplish it; there is, however, now in progress an international photographic survey of the heavens, which, when it is complete, will go far to fill up the void in our knowledge which at present exists; but before speaking of this it

will be better to finish with the work of the Herschels in this department of astronomy. To obtain an idea of it, it will suffice to remember that Sir W. Herschel dealt with 3400 groups. These were not all completely independent of one another, and they must be reduced to the smaller number of 683 in order to obtain the number of the quite independent groups. Herschel is considered to have examined only $\frac{1}{250}$th part of the sky; it would have taken him 83 years to have gone over the entire heavens, allowing that he could have done 100 fields every night, and could have found 100 favourable nights in every year. In some regions the stars were so numerous that Sir William counted 588 in one field of view, and, the telescope remaining stationary, field after field quite as rich passed along as in a panorama for several minutes. At one place he estimated that he had seen 116,000 stars passing before him in a quarter of an hour; and that on another occasion 258,000 stars passed in 41 minutes; on the other hand, in other parts of the heavens fields presented themselves with only two or three stars in them. The results which Sir W. Herschel arrived at were published in 1785. Nearly 50 years later his son, who went out to the Cape of Good Hope for the express purpose of carrying on observations in the Southern hemisphere, took up again this very self-same question of the numbering of the stars. His results, equally as interesting as his father's, differed from them in this particular, that the Southern hemisphere is less uniformly

decked with stars than the Northern hemisphere, and bare places are more common.

By a computation based on the results of gauging both hemispheres, Sir John Herschel found that the total number of stars visible in an 18-inch reflector cannot be less than $5\frac{1}{4}$ millions, but Struve, interpreting Sir W. Herschel's observations in the light of his own, estimated that more than 20 millions of stars were within the grasp of a reflector of the named dimensions.

The most cursory examination of the heavens will make it clear that the stars are very unequally distributed; that in some parts they are very much more closely arranged than in others, and that this is true whether we consider their absolute number or their individual brightness. Various attempts have been made to frame speculations as to the causes and meaning of these facts, but it is obvious that all such speculations must be more or less useless and unprofitable. I may have something more to say on this subject when we come to deal with that wonderful mass of stars which we call the Galaxy, or Milky Way, but an investigation as to the "how" or the "why" there are more stars to be seen in some places than in others would, in the present state of our knowledge, lead to no very definite or satisfactory results.

A few words about the International Photographic Survey of the Heavens which is now in progress. This took its origin from a Conference of Astronomers, representing 16 different nationalities, which met at the Paris Observatory in

April, 1887, on the invitation of the Academy of Sciences of France. The basis on which the undertaking was started was in substance defined as follows:—(1) That the progress made in astronomical photography demands that the astronomers of the present day should unite in obtaining a permanent record of the heavens by means of photography. (2) That the work should be carried out at selected stations, and with instruments which should be identical in size and other essential features. (3) That the principal object to be aimed at is to secure a chart of the heavens for the present epoch, and therewith data for determining with the greatest possible accuracy the positions and brightness of all stars down to a given magnitude, the ultimate idea being that the information thus obtained should be so preserved as to be available in future years for determining whether changes of position or brightness have occurred in respect of any given stars. These preliminary principles having been accepted by the Conference, which comprised 20 representatives for France, 8 for England and the British Colonies, 6 for Germany, 3 each for Russia, Holland, and the United States, 2 each for Austria, Sweden, and Denmark, and 1 each for Belgium, Italy, Spain, Portugal, Switzerland, Brazil, and Argentina, a committee was appointed to consider and report upon the form and size of the instruments to be used and the range of magnitudes to be embraced. After a large amount of anxious inquiry and debate, it was eventually decided that the instruments employed should

be exclusively refractors of 11 inches aperture, and rather more than 11 feet focal length, giving a field of 2° square, the photographic plates being $6\frac{1}{4}$ inches square, and showing an effective square (*réseau*) of $5\frac{1}{8}$ inches, with lines $\frac{1}{5}$ inch apart.

The necessary instruments have been provided, chiefly at the cost of the Governments of the respective countries, and the survey is now well in hand at the following 19 observatories—Helsingfors, Potsdam, Oxford, Greenwich, Paris, Vienna, Bordeaux, Toulouse, Catane, Algiers, San Fernando, Chapultepec, Tacubaya, Rio de Janeiro, Santiago, Sydney, Cape of Good Hope, La Plata, and Melbourne. These observatories range in latitude from 60° N. to 38° S., and may be considered as conveniently placed for embracing the whole sky. It is scarcely necessary to add that the work undertaken is one of enormous magnitude, and, though not actually difficult, requires in a high degree the services of observers well endowed with the virtues of patience and carefulness. The work will, of course, occupy several years, and the final results in a combined form are not likely to be available much before the year 1900.

CHAPTER VII.

DOUBLE STARS.

We have hitherto been considering the stars as isolated points of light dotted hither and thither

all over the heavens and as if they had no connection one with another. These suppositions are only true in a qualified sense, for the telescope reveals the fact that no inconsiderable number of the stars which we regard as simple

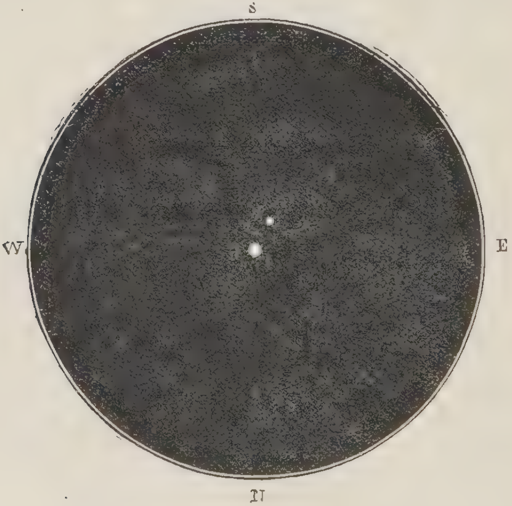

FIG. 5.—α HERCULIS (DOUBLE STAR).

points of light are in reality 2 (or in some cases several) single stars which are so close together as to appear to the naked eye to be one.

The proximity of one star to another might in any given case only be an effect of perspective and not an actual fact. For instance, a man

standing on the top of a straight road which led up a hill might see 2 men approaching him, seemingly walking shoulder to shoulder, as if they were 2 friends engrossed in conversation, whereas in reality they might be isolated individuals walking up the hill, each on his own account, perhaps 50 yards apart. On the other hand, if the man at the top saw the other 2 men cross from one side of the road to the other simultaneously, and that as one turned his head askew, apparently to look at some distant object, the other did the same thing, he might justly infer that the two were really friends and were really walking side by side.

The foregoing illustrations will define with perfect accuracy the difference between what is called an "optical" double-star (that is, 2 stars which seem to be linked together because of the effect of perspective) and a "binary" double-star; that is, 2 stars which not only seem to be linked together but truly are so. These last-named are often spoken of as "physical doubles," or 2 stars physically connected. To determine in any given case whether a pair of stars belong to the one class or the other is a matter involving both delicate observations and laborious calculations. More than a century and a quarter ago Michell suspected that there might be a physical connection subsisting between certain stars by considering the probable chance of producing a purely accidental combination if a batch of stars were, so to speak, promiscuously thrown haphazard into space. He found that the chances of bringing

together stars such as the Pleiades, of their brightness and at their distance, was 500,000 to 1, of 1500 stars visible. The improbability became much greater if the inquiry was based upon the case of stars of the 2nd and 3rd magnitudes and within a few seconds of arc of one another. Yet in point of fact we have several examples of this kind, such as α Centauri and α Geminorum.

But probability does not suffice to establish the truth of a fact. One draws a much more conclusive argument from a consideration of the actual proper motions of the stars where such can be detected. If the stars were accidentally brought together, as they are generally of different magnitudes, their proper motions, both real and apparent, would also differ; consequently with the lapse of time they ought to separate from one another. Yet it happens that many of these stars, though exhibiting considerable actual motion, preserve very much the same distance from one another during an extremely long interval of time. Such are the two stars composing α Centauri, α Geminorum, γ Virginis, ζ Ursæ Majoris, and a great number of others, pairs of unequal size. α Centauri, the two constituent stars of which were separable with difficulty in a telescope 100 years ago, has such a considerable proper motion that the two stars ought now to have become separated by an interval of 6 minutes if the proper motion of the one were not shared in by the other. This, perhaps, would not always be an unfailing criterion,

because it might so happen that the proper motions only exhibited small differences, notwithstanding the extent and reality of the difference. What, after all, would in any given case plainly decide the question would be the positive fact (where it could be established) that one star turned around the other in a closed orbit in seeming accordance with the recognised principles of the law of gravitation. This great discovery has indeed been made, and we owe it to Sir William Herschel. When that remarkable man had sufficiently perfected his instruments, so that he could penetrate into the depths of space in a way never before attempted by any of his predecessors, he set himself the task of seeking to discover stellar parallax, or the actual distances of the stars from the earth. He selected for his purpose certain large stars which were accompanied by small companions at a distance of only a few seconds of arc. He measured these distances with great care by means of an instrument of his own invention called a "micrometer," which also enabled him to determine the angle made by a line passing through two stars with the meridian. He called this angle the "angle of position" of the two stars, regarding the larger of them as the determining centre of the arc on which the measurement was founded. If there had been any annual parallax—that is to say, any apparent displacement of the stars with respect to the celestial background, as a result of viewing the stars from opposite points of the earth's orbit at 6-monthly intervals—that

parallax would have been discoverable because there would have been disclosed a variation in the distance or angle, comparing one time with another separated by the interval of 6 months. However, after numerous and painstaking researches, carried out with every attention to detail, Herschel could not satisfy himself that he had obtained any proofs of change, and he gave up the work for a time in despair. Having afterwards improved his instrumental means, he

FIG. 6.—ζ HERCULIS (1865).

FIG. 7.—ζ HERCULIS (1871).

resumed his labours, hoping for better results. Great was his surprise to find that some of the stars which he had formerly seen double had become single, the junior member having disappeared, whilst others had evidently changed both their angular position and their distance. Though all hope of discovering an annual parallax seemed to have vanished, at least he had obtained traces of a parallax of another sort, due either to a general movement of the whole

system or to some special movement appertaining to particular stars. Michell's old idea seems to have recurred to Herschel's mind and to have stimulated him to further effort, and after several additional years of painstaking and laborious work, at length in 1802 he found himself in a position to announce to the scientific world his grand discovery that there existed systems formed by pairs of stars revolving about each other in regular elliptic orbits. He coined the word "binary" and gave it to these stars, to distinguish them from mere optical double-stars, which do not exhibit any mutual periodic changes of place.

FIG. 8.—ζ HERCULIS (1883).

The interval that elapsed between Sir W. Herschel's abandonment of his first researches and his renewal of work was about 25 years. This is a period quite sufficient to enable the motion of many binary stars to become evident to the senses, and accordingly no fewer than about 50 stars were noticed by Herschel to have undergone change during the time that his operations were suspended. True that his stars had, for the most part, only had time to traverse a portion of their orbits, but more than 90 years having elapsed since Herschel's announcement of 1802, it follows that a certain number

of binary stars have not only gone entirely round in their orbits once, but some of them have done so almost twice, and the form and dimensions of their orbits are now fairly well understood. To cut a long story short, it may be stated that fully 200 pairs of stars are now recognised to be in motion round one another in obedience to laws probably identical with what are known as the laws of gravitation, though for obvious reasons their orbits have not all been investigated with equal completeness and accuracy. The following are the names and particulars of a few of the binary stars with periods of less than 100 years, the nature of whose movements has been ascertained with fair certainty :—

Name of Star.	Period.	Date of Last Passage.
	Years.	
42 Comæ Berenices	25	1870
ζ Herculis	34	1864
η Coronæ	41	1891
μ^2 Herculis	45	1880
Sirius	49	1893
ζ Cancri	59	1868
ξ Ursæ Majoris	60	1875
α Centauri	77	1875
γ Coronæ	85	1840
70 (*p*) Ophiuchi	94	1808

Sir W. Herschel's original observations had reference only to pairs of stars, but the further attention which has been given to this subject of late years has resulted in the discovery of the

fact that in certain cases there exist systems of stars in triplets, each member of which system has a relation to the other two, which justifies their being called not simply triple stars but "ternary" stars. ζ Cancri is an object of this type.

It must be added, by way of caution, that though movement on the part of a pair of stars during a course of years is *primâ facie* a proof of physical connection involving motion in a closed orbit, yet this must not be regarded as a rule of universal application. A mere angular displacement may, in a given case, be the effect of individual proper motion on the part of one or both of the stars of a pair, and not the effect of a central force. From this it will follow that sometimes the positions successively occupied by the principal star will not exhibit the line of a sensible curve. Flamsteed's 61st star in Cygnus seems to be one of this character; it is moving, but its motion is in a straight line.

Before passing away from the subject of double stars, a word should be said about the remarkable circumstances of 2 stars which are well known by reason of their great intrinsic brilliancy—Sirius and Procyon. Both these stars are subject to peculiar disturbances of place, which long excited the surprise and curiosity of astronomers. It was suggested that these disturbances were due to the presence of some invisible satellite, and in the case of Sirius this surmise has proved well founded. In 1862 Alvan Clark, a well-known American optician, found near Sirius a minute companion, the

existence of which has enabled astronomers to explain some, though perhaps not all, of the irregularities found to exist in the positions of the primary star at different times. Arising out of this is the further conclusion that this faint attendant, which has only $\frac{1}{12000}$ of the light of Sirius, possesses a mass more than $\frac{1}{4}$ of Sirius. In other words, unless it does thus really approximate in mass to Sirius itself, it is not capable of accomplishing the observed disturbances. That disturbances are traceable in the movements of Sirius is no new idea, for the great German astronomer, Bessel of Königsberg, as far back as 1844, not only noticed their existence but suggested the presence of an invisible perturbing body, belonging to the system of Sirius, as an explanation of the fact that the proper motion of Sirius takes place not in a regular line, but in an irregular sinuous line. Accordingly, he suggested that this very bright star possessed a dark satellite. Other astronomers worked at the idea, and may be said to have paved the way for the actual discovery of the satellite by Clark.

A very interesting question often presents itself to students of astronomy, who meditate on what they have seen after they have examined double stars. The question may be put in this form: We on the earth are placed on a certain moving body called a planet, which is one of a number of planets circulating round the sun as their chief ruler or centre. Is this state of things unique? Or, on the other hand, do other suns exist? Or, to be more precise, do other

bodies exist in the universe which are centres of life and motion analogous to our sun? No one who has seen a bright double star, with its one or more companions, and still more, no one who has seen the many bright stars with companions which are to be found scattered up and down the heavens, can doubt that the answer to the above main question must undoubtedly be in the affirmative. In other words, that there are in the universe many suns, each with its own *cortège* of planets, and not one sun only. Much beyond this, however, we cannot go. One thing is not a matter of speculation. Whereas our planets revolve round the sun in orbits, which though not truly circular, are yet not very eccentric; that is, do not depart much from the circular form, yet in the cases of the binary stars, the orbits of all that are known depart very much indeed from the circle. Secchi has well pointed out that if we consider for a moment what is involved in the existence of luminous systems of stars, we may well be struck with the inferences which necessarily follow. In the case of a system the form of whose orbit is very eccentric (such as α Centauri), any attendant planets must be warmed sometimes by 2 suns very near, sometimes by one sun very near, and by another very far off. Who can calculate the transformations of life which go on under such circumstances without remembering the wisdom of Him who often with small apparent means is able to bring about an infinite variety of results? Add to this the fact that double stars very often exhibit different

and complimentary colours. The imagination of even a poet would be incapable of describing to us the phases of a day illuminated by, say, a red sun, and of a night illuminated by, say, a green sun, or of a day in which 2 suns of different colours competed with one another, whilst the night was ushered in by a golden twilight and the next morning was preceded by a blue dawn. But I do not wish in this chapter to drift into star colours, for that is a subject of sufficient importance to deserve a chapter to itself.

CHAPTER VIII.

FAMILY PARTIES OF STARS.

The subject matter of the preceding chapter will naturally suggest the idea that if one naked-eye star is found telescopically to consist really of 2 stars, why not another of 3 stars or 4 stars, or more, in close association physically or apparently? And such, indeed, is the case. We have, accordingly, plenty of triple stars, some quadruples, some quintuples, some sextuples, and so on—many of them very picturesque to look at through a telescope. Amongst the triple stars within the easy reach of amateurs armed with small telescopes may be mentioned Flamsteed's 11 Monocerotis, 12 Lyncis, and 51 Libræ. The following are quadruples :—π^2 Canis Majoris, 8^2 Lacertæ. β Lyræ is a quintuple. Again there are some stars which comprise so many

constituents that they can best be described as "multiples"; such are ε Lyræ and σ Orionis.

It will be seen from the engravings that each of these exhibits a double system of stars, so that ε Lyræ may be called a double-double, whilst σ Orionis is a double-triple. The former object comprises one pair of stars of mags. 5 and $6\frac{1}{2}$, whilst the second pair are 5 and $5\frac{1}{2}$ respectively. There seems every reason to sup-

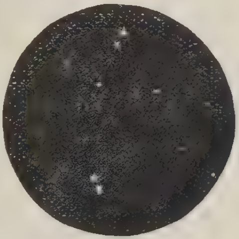

FIG. 9.—ε LYRÆ.

FIG. 10.—σ ORIONIS

pose not only that the 2 stars of each pair

constitute a binary system (each star revolving round the other), but that each pair taken together revolves round the other pair, thus constituting a double-binary, or a system of mutual association of great complexity. Between the 2 main pairs there are several

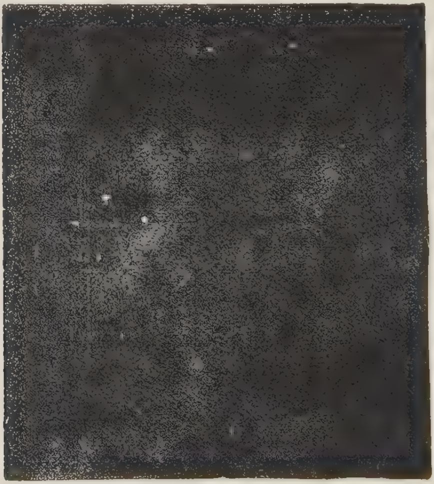

FIG. 11.—θ ORIONIS.

smaller stars. Many telescopes will show 3, and Professor Hall, in America, has made the 3 into 7, but his additional stars are very faint indeed, and can only be seen in the very largest telescopes. ϵ Lyræ is on the frame of the Lyre, $1\frac{1}{2}°$ N.E. of the very bright star Vega.

The group forming σ Orionis, whilst it bears a certain family resemblance to ε Lyræ, differs from it in the respect that we have no knowledge of any of the stars being linked together so as to constitute a moving system. σ Orionis may be easily found, as it forms the southern vertex of a triangle with the 2 last stars (ζ and ε) in Orion's Belt; and it is rather less than a degree from ζ in the direction of β.

Orion contains another multiple star of great interest known as θ Orionis. In this case there are 6 stars, the four most conspicuous of which make a trapezium at distances not very unequal. The 5th and 6th stars are fainter, and lie just outside the boundary lines of the trapezium. In this case the component stars are not organised in pairs, and do not appear to constitute a system physically connected. θ Orionis is in the midst of the "Great Nebula in Orion," of which more anon. Perhaps it might even be said to form a part of the nebula.

CHAPTER IX.

COLOURED STARS.

Most persons would say on a casual glance that the stars are specks or points of white light, and so no doubt the majority of them are; but more attentive examination will disclose the fact that a very considerable number of them exhibit definite colours, though those in which any colour is very pronounced are in a great minority.

The student who is familiar with the intense colours of the solar spectrum will be disappointed if he expects to find amongst the stars many colours as pronounced as those which he sees in the solar spectrum. Nevertheless, it is possible in a general way to find here and there stars which if they were all brought together in a row would constitute some similitude of the solar spectrum.

There are many difficulties in the way both of observing and of recording the colours of stars, and this explains the discrepancies in the accounts put forth by different observers. In the first place, people's eyes are differently constituted; some eyes are more capable than others of accurately appreciating and describing a colour. Some eyes, indeed, as is well known, are totally incapable of appreciating certain colours at all. Possessors of such eyes are said to be "colour-blind." But, disregarding extreme cases of this sort, it is quite certain that ordinary eyes will differ not a little in appreciating a given colour. It suffices to visit a picture gallery and take note of the differences in the copies of one and the same original picture which are being made by different copyists, to realise the fact that particular hues in the original are reproduced in a very different way by the different persons.

Then, again, the quality of the glass of the telescope employed influences much the apparent colours of the objects looked at; and still greater is the effect of the good or bad grinding of the lenses. In other words, lenses made of very pure glass and very accurately ground and

polished will yield images and indications of colour which will be much more true to nature than the indications afforded by inferior glass inaccurately figured. It is a very noteworthy fact that metallic mirrors always give to objects seen through them a reddish tinge. This is strikingly brought out in connection with Sir John Herschel's observations of red stars. To many of these objects he has attached such qualifying words as "carmine," "ruby," "intense crimson," where ordinary observers employing ordinary telescopes would see only ordinary red hues. Nor is magnifying power entirely an unimportant matter; with a low power white will dominate, and other tints will in a measure be lost, because no star is absolutely mono-chromatic; on the other hand, a high magnifying power diminishes the total light, and, exaggerating the dimensions of the spurious discs, renders the colours more easily distinguishable. Again, the state of the atmosphere and the proximity of a star to the horizon greatly affect its appearance. It is only when a star is well up in the heavens above the horizon that its true colour, whatever it may be, can be noted, because near the horizon all celestial objects apparently acquire red or orange hues, which do not really belong to them.

Perhaps the greatest of all the difficulties which beset the observer who wishes to make an accurate record of star colours, is the difficulty of providing and using a standard of colour for comparisons. Such a standard is furnished naturally by the solar spectrum; but astro-

nomers have hitherto been altogether baffled in their attempts to reproduce the prismatic colours in such a way that they can be rendered practically available in the darkness of night, side by side with the image of a star produced at the eye-end of a telescope. There is herein, in point of fact, a double difficulty; that which may be called the manual or mechanical difficulty just alluded to, and that which arises from the fact that the artificial light employed by night being yellow, injures the neutrality of the eye and falsifies all artificial colours. It was with the idea of getting over these difficulties that Secchi proposed to make use of an electric spark, which, if derived from different substances, would give for each of them a different hue, but I am not aware that any attempt has ever been made to put this idea into practice.

Single stars of a red or orange hue are not uncommon, but isolated blue or green stars are very rare. Indeed, β Libræ appears to be the only conspicuous star which is green. In the case, however, of double stars it is much more easy to define their colours, for in many instances they exhibit very well-marked colours, and frequently the colours of the 2 stars are what are called "complementary." The reader may be reminded that this is a term applied by physicists to the colours which, when united, make white light. In order to obtain a strictly exact idea of what these colours are recourse must be had to a special instrument of which several kinds have been contrived. But for the elementary purposes of this work it will suffice to state

that the principal pairs of colours which are mutually complementary are red and green, orange and blue, and yellow and violet. The intermediate tints are too innumerable to be described in words, and they can only be realised by instrumental means.

When we speak of double stars as exhibiting different colours it is not permissible in all cases to regard the colours as an optical illusion or an effect of contrast, for in some instances certainly the colours are an actual physical reality. We may draw this conclusion in some cases from the circumstance that the colours seen are not always complementary; and in other cases from the fact that, by concealing the principal star by means of a bar in the eye-piece, formed of watch-spring or something of that sort, we shall notice that the companion star, when thus cleared of the effects of its primary, preserves its colour unchanged.

The following may be mentioned as good examples of coloured pairs:—

	Large Star.	Companion Star.
η Cassiopeiæ ...	Yellow ...	... Purple
α Piscium ...	Pale Green	... Blue (or var.)
γ Andromedæ ...	Orange ...	... Green
ι Cancri	Orange ...	... Blue
ε Boötis	Pale Orange	... Sea Green
ζ Coronæ	White ...	... Blue
α Herculis ...	Orange ...	... Emerald Green
β Cygni	Yellow ...	... Sapphire Blue
σ Cassiopeiæ ...	Greenish	... Bright Blue

Secchi compiled the following list of conspicuous stars of the colours stated:—*White*,

Procyon, Altair; *Blue*, Sirius, Vega, Castor, Regulus; *Yellow*, Capella, Pollux, *a* Ceti; *Orange*, Aldebaran, Arcturus, Betelgeuse; *Ruddy*, Antares, *a* Herculis.

Krüger, an experienced German observer, has given the following list, which, it will be seen, is not wholly in accord with Secchi's:—*White*, Sirius, Altair, Regulus; *Yellow*, Capella, Pollux, Arcturus; *Orange or Red*, *a* Herculis, Betelguese.

All the really red stars—that is, stars of pronounced depth of colour—are comparatively small in size—scarcely, if at all, visible to the naked eye. There are a few—perhaps half a dozen—to which the designation "carmine" may be applied, but the bulk of the so-called red stars are more orange than red. I shall have something more to say about some of these in the chapter on "Variable Stars."

The question of whether the stars vary in colour has attracted some attention, but the evidence is, on the whole, meagre and inconclusive. From a passage in Seneca, an ancient Roman writer, it has been inferred that he wished it to be understood that in his day Sirius, the Dog Star, was red, whereas now it is white, or bluish-white. Ptolemy seems also to have regarded Sirius as a red star, and to have used a word to describe it which he also applied to Pollux. Now Pollux is certainly a reddish-yellow star in the present day, and if it and Sirius could ever have been appropriately designated by the same adjective of colour, then the conclusion follows as a matter of course that Sirius no

longer exhibits the colour it once did. Capella is perhaps another star which has changed from red, or reddish, to blue—but one could have wished for a larger number of instances. At present we can only say that whilst change of brilliancy in the case of stars is a common occurrence, change of colour is not a well-established fact.

CHAPTER X.

MOVING STARS.

THE term "fixed stars" is a familiar one, and in a certain sense it is the expression of a truth, but modern science has shown that the term, as applied to the stars, needs to be employed under reserve, for a great many stars are not "fixed." I am not, of course, alluding to their apparent annual or diurnal movements: we have considered that matter in a previous chapter, and I hope the reader understands by this time (at any rate generally) what these apparent movements are and how they arise. What we have now to deal with is actual proper motion, and with this a considerable number of the stars are endued.

It must be understood, of course, that though the ancients divided the stars into two classes—those which were stationary, and those which moved—they knew nothing of the stars which form the subject of this chapter being moving stars. The objects to which the ancients applied the designation of "wandering stars" were what

we now call Planets, or Comets. Indeed, the very word "planet" itself is derived from a Greek word meaning "a wanderer." What we have now to consider are the movements of certain stars, which movements are, as a rule, very small in amount, and proceed very slowly. Sir John Herschel's statement of the case can hardly be improved on. He says:—"Motions which require whole centuries to accumulate before they produce changes of arrangement such as the naked eye can detect, though quite sufficient to destroy that idea of mathematical fixity which precludes speculation, are yet too trifling, as far as practical applications go, to induce a change of language and lead us to speak of the stars in common parlance as otherwise than fixed. Small as they are, however, astronomers once assured of their reality have not been wanting in attempts to explain and reduce them to general laws."

What the expression the "proper motion" of a star means or involves may perhaps be best understood by some such illustration as the following:—A man standing in Trafalgar Square and looking down Whitehall may at a given moment see in the direction of the Houses of Parliament an omnibus, a cab, and a van. After an interval of 2 minutes he may see the same vehicles, but their order may be first the van, then the cab, and lastly the omnibus. This may imply either—(1) that the van has remained stationary, the omnibus and the cab having moved forwards, the omnibus travelling at a more rapid pace than the cab; or (2) that all three have moved somewhat, but each at a

different pace; or (3) that the van has backed towards Trafalgar Square, only the omnibus and the cab going forward If such a condition of things were conceived to be transferred to the heavens, our ideal omnibus, cab, and van being transformed into stars, we should have an analogue of the problem which the astronomer has to solve in detecting and valuing the proper motions of 3 neighbouring stars, or, it may be, of only 2, or perhaps even of only 1, of such stars. Be it remembered, too, that in the illustration I have given it may well happen that the Trafalgar Square spectator, from his position astride of one of Landseer's lions, though he may be quite sure that the omnibus and the cab have both moved forwards, may yet be totally incapable of determining whether their movement amounts to 10 yards or 50 yards, because he is viewing the whole proceeding "end on," or, in astronomical language, the 3 vehicles are nearly in his "line of sight." Things would, however, present quite a different aspect to a second spectator standing, say, in front of the Horse Guards. His would be a "broadside" view of the several vehicles; and whether they had all moved, or, if only some of them, then which of them, and how much had each moved, would be points upon which he could pronounce an opinion promptly and (let us hope) accurately.

The above simile in each and all its stages and aspects may be taken to be a counterpart of the problem presented to an astronomer called upon to investigate stellar proper motions. And what Fontenelle once said in respect of the star

known as Altair in the constellation Aquila is on all fours with the illustration which I have borrowed from what may be seen any day at Trafalgar Square. Said Fontenelle:—"There is a star in the Eagle which, if all things continue their present course, will, after the lapse of a great number of ages, have to the west another star which at present appears to the east of it." * Fontenelle's remark is just such a remark as my ideal spectator at the Horse Guards might make because of his enjoying a "broadside" view of the changes in the positions of the vehicles going down Whitehall. But the original spectator at the Nelson Monument has also his circumstances reproduced in the heavens; for, even though in the case of any given star no indications, or but slight indications, of lateral change of place can be detected, yet such star may nevertheless be endued with a rapid motion of either approach or recession which can be found out by a secondary method. Thanks to the spectroscope and the ingenuity of modern astronomers, motions of approach to or recession from the earth have been discovered in the case of certain stars, notwithstanding that those stars, being seen "end on" (*alias*, in the line of sight), seem

* Referring to the diagram of the stars in Ursa Major, given on p. 36 (*ante*), it may be noted that all 7 are endued with proper motion; but whilst β, γ, δ, ε, ζ are moving one way, α and η are moving the opposite way, and Fontenelle's remark (varied as necessary) finds a further exemplification. Various examples may be found of stars in proximity having common proper motions or, as Miss Clerke words it, having a "gregarious tendency."

on mere visual observation to be practically stationary.

But I am anticipating too much. The fact that certain of the stars are endued with a proper motion of their own was first ascertained in 1718 by the English astronomer Halley. By comparing the positions of Sirius, Arcturus, and Aldebaran, as laid down in the most ancient catalogues, with the positions determined by himself in 1717, he found, after making every allowance for the effects of precession and the variation in the obliquity of the ecliptic, that these stars seemed to have got out of place to the extent in each case of more than $\frac{1}{2}°$, a displacement too considerable to be ascribable to errors of observation or errors of copying. In the case of Aldebaran it was further found that that star had undergone at Athens in 509 A.D. an occultation by the Moon which could not have taken place if the star had occupied 1400 years ago the same or nearly the same place that it occupies at the present time. The utmost that Halley could do was to surmise that the stars in question were affected by proper motion, because in those days no long-continued series of observations of places taken by exact instruments were in existence. Such observations, however, soon began to accumulate as the 18th century rolled on, and accordingly in 1738 James Cassini was able to say with some confidence that Arcturus had undergone a displacement of 5′ in a century and a half, whilst the neighbouring star η Boötis had been exempt from such displacement. Inasmuch, however,

as precise and exact instrumental observations of star places can only be said to date from 1760 (being the epoch of Bradley's Catalogue of important stars) and as that was only a century and a quarter ago it is evidently clear that the study of stellar proper motions must be regarded as a branch of the science which is still in its infancy, especially seeing that in the case of the star having the largest known proper motion (1830 Groombridge Ursæ Majoris), the amount is only 7″, and that only in the case of about a dozen stars does the amount exceed 3″. It was to a fact such as this that Sir J. Herschel alluded in the paragraph quoted on a previous page, when he spoke of "motions which require whole centuries to accumulate before they produce changes of arrangement such as the naked eye can detect."

Year by year is adding to the number of the observations, which by their exactitude enable us to detect proofs of proper motion when those observations are placed in juxtaposition with observations of the same stars made in the earlier part of the present century, say between 1800 and 1830. The materials already available seem to point to the fact that the proper motions of the brighter stars are, as a rule, greater than those of the fainter stars. The average proper motions of the 1st magnitude stars known to possess proper motions has been set down at $\frac{1}{4}''$ annually, whilst the average displacement of the 6th magnitude stars known to be affected amounts to no more than $\frac{1}{25}''$.

This law, if law it may be properly called, is subject to exceptions, for there are some small

stars, such as 1830 Groombridge Ursæ Majoris, 9352 Lac. Piscis Australis, 61 Cygni, 21185 Lalande Ursæ Majoris, and 21258 Lalande, which have very considerable proper motions.

The reader who has followed attentively the Trafalgar Square illustration will have no difficulty in understanding the statement that a knowledge of a star's proper motion conveys very little information as to the said star's real motion reckoned in miles per second. When we say that a star's proper motion amounts to 4″ a year (which is about 6½′ in a century), the record is simply that the star's apparent lateral displacement is so much in such a length of time along a line assumed to run at right angles to the observer's line of sight. But the true direction may not be at right angles as aforesaid; it may be in a path which the observer may only see foreshortened. Or, in an extreme case, if the motion takes place directly in the line of sight so that the star is moving straight towards us, or from us, it may be in rapid motion and yet visually seem to have no motion at all; that is, to be undergoing no change of apparent place which can be detected by comparing observations taken at different times.

Whilst it cannot be said that we know much about the actual motions of many of the stars, yet we do know something. The spectroscope furnishes us with some clue, the basis of which is a principle of physics first enunciated by Doppler in 1842. This principle may be thus defined:—"When the distance between us and a body which is emitting regular vibrations either of

sound or light is decreasing, then the number of pulsations received by us in each second is increased, and the length of the waves is correspondingly diminished." In the case supposed the musical pitch rises, and in the same way the refrangibility of a wave of light which depends upon its wave length is increased so that it will fall nearer the violet end of the spectrum. A practical illustration of this principle may often be had by a person standing on the platform of a railway station through which a fast train is passing at a high rate of speed, whistling continuously as it passes. It will be noticed in such a case that the pitch of the whistle continuously varies as the train approaches the spectator, whilst it goes on continually varying, but in the opposite direction, after it has passed him and the distance gradually augments. Whatever was the pitch, say, at 200 yards, before the engine came up to the platform, the pitch will be the same at 200 yards in the opposite direction after the engine has passed the platform.

Huggins, in 1868, thought to apply the foregoing principle by spectroscopic observations on certain stars with a view of seeing whether a particular line in a spectrum underwent after an interval any displacement from its normal position towards either end of the spectrum. If in any given case there was a displacement towards the red end of the spectrum, the conclusion would have to be that the star was receding from the earth: if, on the other hand, the displacement was towards the violet end of the spec-

trum, the conclusion would have to be that the star was approaching the earth. A general deduction to be drawn from the observations of Huggins and of others who have worked in the same field, seems to be that there are several dozen prominent stars in motion at speeds varying from 2 to 50 miles a second.

When astronomers once came to recognise the fact that certain stars were in motion it naturally followed that there was a desire to ascertain whether any particular consequences, and if so what consequences, were involved in the discovery. Sir. W. Herschel in 1783 began by trying to classify the proper motions of the stars, so far as known to him at that epoch. Having done this and finding evident signs that they converged towards a point in the Constellation Hercules, he was led to conclude that the Solar System as a whole was moving towards a point in the Celestial Sphere not far from the star λ Herculis. The principle involved has been thus defined by Professor Young:—"On the whole, the stars appear to drift bodily in a direction opposite to the sun's real motion. Those in that quarter of the sky which we are approaching open out from each other, and those in the rear close up behind us. The motions of the individual stars lie in all possible directions, but when we deal with them by thousands, the individual is lost in the general, and the prevailing drift appears."

The effect here stated by Young may be seen, and being seen, may be easily realised, by walking through a field dotted over with units of any

kind, such as sheaves of corn put up in shocks, or haycocks, or any similar aggregations of produce. As the pedestrian approaches a row of such things, the row which at a distance seemed almost continuous will be found on nearing it to have its units separated by several feet or yards of distance: as he passes forwards across the field the first and subsequent rows will gradually seem to close up behind him into a more or less compact mass.

Sir W. Herschel's endeavours to find out the "apex" of the sun's way (as it is called) have been followed up by other astronomers since, and about 20 different determinations are now available. There is a remarkable general accord between them all. Perhaps on the whole the most trustworthy because it is based upon a very large number of stars is L. Struve's. He has found the point of convergence to be situated in R. A. 18h. 13m.; and Decl. + 27°. Huggins, by spectroscopic observations of an ingenious character, has confirmed the general conclusions thus stated.

A skilful and careful German astronomer, named Mädler, at that time employed at the Observatory of Dorpat in Russia, put forth, in 1846, an idea that there exists some central point in the universe around which the sun, with its bevy of planets and comets revolves in the course of millions of years; and he suggested that such centre is situate in the direction of Alcyone, one of the Pleiades. It is difficult to pronounce dogmatically for or against this idea (which, by the way, was rather a revival of a

theory put forth by Wright in 1750 than Mädler's own), but Grant's remarks may be considered to meet the case:—"It is manifest that all such speculations are far in advance of practical astronomy, and therefore they must be regarded as premature."

CHAPTER XI.

TEMPORARY STARS.

Historians of various dates and nationalities tell us that from time to time stars have blazed forth in the heavens in places where no stars had ever been seen before, and that after an existence of, it may be, a few weeks or months, such stars have faded away and been no more seen. There was at one time a disposition to consider that the authors of these statements had been drawing upon their imagination for their facts, but there is no room for doubt that the bulk of the statements which have been handed down to us are well founded. About 12 stars in all are recognised by astronomers under the designation of "temporary stars." They severally appeared as follows: 134 B.C., 329 A.D., 1572, 1600, 1604, 1670, 1848 (*Nova* Ophiuchi), 1860 (T Scorpii), 1866 (T Coronæ), 1876 (*Nova* Cygni), 1885 (*Nova* Andromedæ), and 1892 (*Nova* Aurigæ). Besides these there are others, the recorded accounts of which are very uncertain. The chief difficulty in regard to all the more ancient cases has been to deter-

mine how far the celestial objects thus recorded to have burst forth were in any true sense stars, or whether they were comets or mere meteors. The records which we have are of very diverse origin, and some of them 2000 years old, handed down to us from times when the scientific precision and verbal accuracy of modern writing and speech were unknown. The fact that the ancient Greeks were a dreamy people, the Romans callous to science altogether, and the Chinese "flowery" as nowadays, renders it extremely difficult for us to sift the wheat from the chaff, and to *préciser*, as the French say, any given statement. For instance, what is one to make out of the following Chinese account of something seen in A.D. 173:—"On Dec. 10th a star appeared between α and β Centauri, and remained visible for 7 or 8 months; it was like a *large bamboo mat* (!), and displayed 5 different colours." Were it not for the fact that on several occasions during the present century new stars have burst forth, have shone for a while, and have then either disappeared absolutely or dwindled almost to invisibility, we should often have to be sceptical as to the tales told us by many ancient chroniclers.

Our sources of information are twofold—European and Chinese. The former are generally very vague as to dates and places; the latter much more "understandable," though both dates and places are often expressed in a very peculiar fashion. The Chinese observations have the great merit that they are continuous through many centuries, and are expressed in language

of very uniform style; so that once get an insight into the style, and a European astronomer may feel sure that he can interpret with tolerable accuracy the entire series, and this is what has been done. The first workers in this field were certain French Jesuit missionaries, named Couplet, Gaubil, and De Mailla, who lived for a while at Pekin some 150 years ago. They made and brought to France copies of various Chinese annals, which somehow or other they got hold of at Pekin. De Mailla's manuscripts were published at Paris about 100 years ago, but those of Couplet and Gaubil still remain, I believe, unpublished. A very industrious Frenchman named Pingré worked up all these materials in a book on comets which he published in 1784, whilst another Frenchman named Biot in 1846 gave to the world a further series of observations. By far the most complete and accurate, however, of all the existing versions of the Chinese astronomical records is the late John Williams's "Observations of Comets from B.C. 611 to A.D. 1640," which appeared in 1871.

All this is a digression from the subject which I wanted to start with, but it is a digression which seemed necessary under the circumstances of the case.

The earliest "new" star appears to have been one observed by the Greek astronomer Hipparchus, and a tradition, fathered by Pliny, has always suggested that it was the appearance of this star which prompted Hipparchus to compile his, the first catalogue of stars. This tradition was long regarded as a

myth, but as a new star in Scorpio is recorded by the Chinese to have been seen in 134 B.C., a few years before the date commonly assigned to Hipparchus's Catalogue, there seems now no sufficient reason for rejecting the tradition above referred to. Passing over new stars asserted to have appeared in 945 A.D. and 1264 A.D., the authenticity of which is gravely doubtful (the accounts probably referring to the great comets of those years), we come to the year 1572. In that year there was a celebrated new star with which Tycho Brahe's name is often linked, because he left behind him a particularly full account of it. It was visible for 17 months from November, 1572, to March, 1574. Brighter than Sirius, it rivalled Venus. It changed colour from white to yellow and red and then back again to white, and remained stationary all the while that it was visible. D'Arrest pointed out in 1864 that within 1′ of arc of the place assigned by Argelander to Tycho's star there exists a small star, which Hind and Plummer found in 1873 to be certainly variable in its light. The position for 1890 of Tycho's star is R.A., 0h. 18m. 40s.; Decl. + 63° 32′·3. Amateurs possessed of telescopes, say of 3 inches aperture, might usefully employ their time in finding and watching this supposed Tycho star. It follows a certain 9th mag. star at a distance of 21·6s., and is 10′ 4″ to the S. This 9th mag. star may itself be identified by reason of the fact that it follows a star known as Flamsteed's 10 Cassiopeiæ (mag. 6) at a distance of 17m. 12s., and is 6·4′ to the N. of it.

In 1604 and in 1670 temporary stars of considerable brilliancy became visible. The star of 1604 appeared in Ophiuchus, and grew to be nearly as bright as Venus, lasting 12 months or longer. The star of 1670, often called "Anthelm's star," appeared in Cygnus, and reached the brightness of a star of the 3rd mag. It lasted altogether about 2 years, but faded away and then brightened up again more than once before its final disappearance.

In April, 1848, a new star of the 5th mag. was seen in Ophiuchus by Hind. It eventually rose to the 4th mag., and then faded away and became very small, but has never entirely disappeared. This star is now ranked as a recognised variable, but it seems not to have received much notice of late years.

In 1866 a very remarkable transformation took place in the case of a star which had been previously recorded in 1855 by Argelander as being of the 9th or 10th mag. Birmingham at Tuam, on May 12, 1866, found the star shining as of the *second* mag. Combining the testimony of Birmingham with that of Schmidt of Athens, it would seem that this star brightened up from the 4th to the 2nd mag. in about 3 hours on the evening of May 12. It soon began to lose light, and after diminishing to below mag. 9 it rose to 7½ in September, and remained at that for the rest of the year. This star also is now treated as a recognised variable, though we have gained very little additional knowledge respecting it.

In November, 1876, after several days of

pronounced bad weather, Schmidt at Athens observed on the 24th a new star of the 3rd mag., yellow in colour. By the beginning of December it had sunk to the 5th mag., and by the end of December to the 7th mag., and now it seems to have disappeared altogether.

In August, 1885, a new star burst out in, or in front of, the Great Nebula in Andromeda. Though it only reached the 6th mag., yet, owing to the large number of telescopes and spectroscopes brought to bear on it, this *nova* has a considerable and very interesting history attached to it.

Reserving for the chapter on the Spectroscope (*post*) a statement of what that instrument told us respecting this star, I will here state historically what seems to have happened. The Great Nebula in Andromeda is one of the largest and most important of the known nebulæ, as we shall see when we come to speak of that class of celestial objects. It ordinarily offers the appearance of an extensive and dense oval mass of luminous haze. It so presented itself to various observers during the first half of August, 1885. Priority in noticing it to be otherwise—that is, as having a star in or on it—seems to rest either with the late Mr. Isaac Ward, of Belfast, or with a Hungarian lady, the Baroness de Podmaniczky, who on August 22 had staying with her at her husband's house a professional astronomer, Dr. De Kövesligethy. There was a telescope of 3½ inches aperture in the house. Hostess and guest several times made use of this telescope, and on August 22 the baroness remarked to

the doctor that she saw a little star in the nebula, a statement which the visitor confirmed. Yet the phenomenon was so faint that both believed the full moon was the indirect cause, the moonlight overshadowing the fainter portions of the nebula, and permitting only of the visibility of the bright centre. It was not till more than a week after the above date that the existence of the new star was generally recognised, though there is evidence to show that some days previously to August 22 the nebula as a nebula had exhibited unwonted brightness. To none, however, of the observers who noted this fact does it appear that the thought presented itself that they were gazing on a stellar object. At its brightest this new star seems to have reached the 6th magnitude, and there is reason to suppose that when Mr. Ward and the Baroness de Podmaniczky saw the star it was rising to, but had not reached, its maximum brilliancy. The date of this may perhaps be put at August 31. The star then rapidly declined in lustre until the end of September, when it stood at about the 10th magnitude. It then further diminished until it became merged in the nebula itself, or rather until its luminosity became lost in the luminosity of the nebula. An interesting question arose as to what were the relations, if any, between the new star and the nebula. A very competent French astronomer named Trouvelot suggested the following reasons for concluding that there was no physical connection between the star and the nebula There are a multitude of small

stars visually scattered all over the nebula. Trouvelot considers these to belong to the Milky Way, of which he traces an extension beyond the nebula, since they increase in number as the Milky Way is approached. They are likewise perfectly sharp and well-defined, which they would not be if they were either in the nebula or behind it. He concludes, therefore, that the nebula lies behind the Milky Way. The well-defined appearance of the new star, and of a small star near it, which he thought was also a new one, seemed to prove that they were both in front of the nebula, and were associated with the Milky Way rather than with the nebula. These surmises, it will be observed, throw no light upon the question why this new star should suddenly have blazed forth and as suddenly have faded away. I must, however, add my testimony to Trouvelot's so far as to say that when I saw the new star myself on September 3, in a 6-inch refractor, I could not refrain from entering in my note-book the thought that "the star had nothing to do with the nebula."

On December 13, 1885, Mr. J. E. Gore in Ireland noticed a new star of the 6th magnitude, reddish in colour, situated some 20′ following χ^1 Orionis. It was found to have a beautiful banded spectrum of Secchi's Type III. Six months later it had diminished to below the 12th magnitude. It afterwards increased again, and is now recognised as a variable going through all its changes of magnitude in about 12 months. Why the sudden and special in-

crease of its light in December, 1885, cannot be surmised.

There yet remains another new or temporary star for mention, the history of which is extremely interesting. On February 1, 1892, an anonymous postcard was received by Dr. Copeland, the director of the Royal Observatory at Edinburgh to the effect that a new star of about the 5th magnitude had become visible in the constellation Auriga not far from the star χ. It subsequently transpired that the postcard had emanated from a certain Dr. Anderson, an amateur living in Edinburgh, who had discovered the star by the joint use of a small pocket telescope and McClure's edition of Klein's "Star Atlas." The history of this star during the weeks immediately preceding its discovery by Dr. Anderson became known in a very curious way. Professor Pickering of Harvard College, U.S. had recently conceived the idea of "patrolling the heavens" every fine night by means of a small photographic transit instrument which would automatically sweep the meridian in a series of steps of sufficient exposure to photograph 6th magnitude stars, at intervals corresponding to the equatorial breadth of the field. The scheme was well adapted for the detection of strange objects brighter than 6th magnitude stars, and so it resulted that Anderson's star was found on 13 photographs taken between December 10, 1891, and January 20, 1892. As it appeared on all these, which embraced stars down to the 9th magnitude, but was not to be found on the

photograph of December 8th, the presumption is that the new star brightened up from below the 9th magnitude between December 8th and December 10th. After remaining at about the 4th or 5th magnitude till the end of February, it diminished somewhat rapidly in brightness, and by the end of March had fallen to below the 12th magnitude. Observations were continued at the Lick Observatory in California till April 26th, when bad weather supervened. It was then of the 16th magnitude, so that it may be said to have practically disappeared. In August, however, it had brightened up again to above the 10th magnitude, finally subsiding to about the 12th magnitude.

I have dwelt somewhat fully on the so-called "temporary" stars, because the subject is one which seems to open up opportunities of scientific usefulness to the class of persons under whose notice this volume is likely to fall—amateurs possessed of small telescopes, or with no telescopes at all, but with many open-air opportunities of becoming familiar with the aspect of the heavens.

It may have been inferred from various remarks made in this chapter that temporary stars, and variable stars, which will form the subject of the next chapter, are so closely associated as almost to imply that all temporary stars are merely variables of long and irregular periods. There is much to support this idea, as also the correlative idea that many of the "missing" stars are also variables not yet recognised to be such. But Kirkwood, an

experienced and thoughtful American observer, considers that the theory that temporary stars are long-period variables is unsound: that the suddenness of their apparition, the short duration of their maximum brightness, and the great length of their periods, if they are really periodic, are reasons for regarding them as distinct in their nature from the variable stars properly so-called. It is worthy of notice that there is no known instance of a new star appearing and remaining permanently visible.

CHAPTER XII.

VARIABLE STARS.

A LISTLESS observer of the stars will regard them as always preserving their brilliancy, be it much or little, unchanged, but such is not the case with all of them; a certain number vary from time to time in their light, and are therefore called "variable" stars. The number of those of which it may be said with certainty that they undergo periodical changes of brilliancy amounts to nearly 300; but it is probable that as many again may be regarded as possibly subject to fluctuations of light. In the absence of absolute standards for comparison, the systematic study of variable stars is a matter involving much patience on the part of the observer and much refinement in his procedure. Were the number of observers endowed with the requisite patience and experience much

increased, there is no doubt that large additions would soon be made to our lists of variable stars. This department of astronomy is entirely modern, for the ancients have left us merely a few vague statements of stars having disappeared, and we can seldom determine with adequate precision the places occupied by them.

Professor Young has made some remarks on the method of observation to be resorted to in the case of variable stars, which it may be useful to quote here. He says:—"There is no better way than that of comparing the star by the eye, or with the help of an opera-glass, with surrounding stars of about the same brightness at the time when its light is near the maximum or minimum; noting to which of them it is just equal at that moment, and also those which are a shade brighter or fainter. It is possible for an amateur to do really valuable work in this way, by putting himself in relation with some observatory which is interested in the subject. The observations themselves require so much time that it is difficult for the working force in a regular observatory to attend to the matter properly, and outside assistance is heartily welcomed in gathering the needed facts. The observations themselves are not specially difficult, require no very great labour or mathematical skill in their reduction, and, as has been said, can be made without instruments; but they require patience, assiduity, and a keen eye."

One of the most celebrated of the periodical stars is o Ceti, otherwise known as *Mira* (the

"wonderful" star), which latter name has been given to it precisely because it undergoes such remarkable changes. Its period is 331d. 8h.; that is to say, it goes through its changes 12 times in about 11 years. At its maximum brightness it sometimes rises to the 2nd mag., remaining thereat for about a fortnight; it then diminishes during about 3 months, becomes invisible except in large telescopes for 5 months, and finally requires another 3 months to regain its pristine maximum brilliancy. These may be taken as average intervals, but it does not always diminish or increase by the same gradations; its maximum brightness is not always the same, nor are the intervals of time between maximum and maximum always identical. These irregularities were studied very carefully by Argelander, who came to the conclusion that the period of 331d. of Mira itself varies in about 88 of such periods, with the result that the single periods gradually lengthen and shorten alternately to the extent of 25 days one way or the other. Moreover, it is not improbable that the irregularities in the star's maximum brilliancy are also periodical, and that at every 11th maximum the star attains to a greater degree of brilliancy than its usual maximum brilliancy. This supposition would explain the fact that whilst the naked-eye visibility of Mira generally extends to about 18 weeks, it was in 1859–60 so observed during 21 weeks, whilst in 1868 the term was but 12 weeks. It was in this year that Heis noted the maximum magnitude to be only the 5th, whilst

in 1888 it attained to about the 3rd mag., and therefore of course remained a naked-eye object for a much longer period. The discovery of the variability of this star dates back as far as 1596. On August 13 of that year David Fabricius noted a certain star in Cetus to be of the 3rd magnitude. In the following October he failed to find it. In 1603 Bayer, in preparing his "Star Atlas," assigned the Greek letter o to a star in Cetus occupying the spot where Fabricius's star had disappeared. He noted it to be of the 4th mag., but being either ignorant of, or neglectful of, the earlier observations of Fabricius, he lost the chance of being able to claim the honour of discovering the star's variability. The spectrum of Mira is a remarkable one of Secchi's IIIrd Type, in which bright lines have been seen.

Perhaps Algol (β Persei) may be regarded as, after Mira Ceti, the second most remarkable variable in the heavens, or, at any rate, in the Northern hemisphere, as it is second also in point of date of discovery. The fact of its variability was noticed by Montanari in 1669, was confirmed by Maraldi in 1694, and investigated half a century later by a Saxon farmer named Palitzch, celebrated for his early detection of Halley's Comet in 1758. But it was Goodricke, in 1782, who first determined in full detail the changes of brilliancy which Algol undergoes. It commonly shines as a star of mag. $2\frac{1}{4}$; from that it descends to about $3\frac{3}{4}$. Pickering, from photometric measures at Harvard College, finds that the star's light diminishes

during 4h. 23m. before minimum. When the minimum is reached, then 5h. 37m. pass before the star regains its normal maximum. It remains at this for about 2d. 10h. The most rapid changes take place during about 100 minutes before and 100 minutes after the epoch of minimum. Pickering suggests that the range of variability is less than is commonly stated, and does not exceed one whole magnitude. The period in which the entire series of changes take place is about 2d. 20h. 48m., and is thought by Chandler to have diminished by 8s. since Goodricke's time; but to talk about 8s. in such a connection is a refinement of precision which savours of affectation.

Another naked-eye variable handy, by reason of its position and magnitude, for observers in the Northern hemisphere is δ Cephei. Its period is 5d. 8h. 47m. counting from minimum to minimum, and its range from about mag. $3\frac{3}{4}$ to mag. $4\frac{3}{4}$. The interval between maximum and maximum is not equally divided by the minimum phase, for it takes longer for the star to pass from its maximum to its minimum than it does to regain its maximum after a minimum. The former transformation occupies 3d. 19h. but the latter only 1d. 14h. The variability of δ Cephei was discovered by Goodricke in 1784, and the whole period is put at 5d. 8h. 48m.

η Aquilæ and β Lyræ may also be mentioned as short-period variables, which on that account, and because they are visible to the naked eye, are specially suitable for observation by amateurs in England.

η Aquilæ varies from about mag. $3\frac{1}{2}$ to mag. $4\frac{3}{4}$ in a period of about 7d. 4h. 14m., but this period itself seems variable. The star is yellow in colour and yields a spectrum of Secchi's IInd Type.

β Lyræ is remarkable as having a double maximum and a double minimum, which together make up a main period of 12d. 21h. 47m. The variations take the following form:—Starting from a maximum when the star is of mag. $3\frac{1}{4}$, it descends to its first minimum of mag. 4; it then rises to the same maximum as before, but in descending to the next minimum it goes down to mag. $4\frac{1}{2}$. Argelander ascertained that β Lyræ resembles Mira Ceti as regards the circumstances of its period—in other words, that its period is itself variable; that down to 1840 the period was increasing, but that after 1840 it began to decrease, and was decreasing at the time when Argelander made this remark in 1866. Pickering has propounded the idea that this star is a "surface of revolution" or a spheroid in form and differently luminous in different parts, and that the epoch of minimum light represents a time when the darker portion at one of the ends is presented to the earth. This seems to be one of those far-fetched fancies which can neither be proved nor disproved. The variability of β Lyræ was discovered by Goodricke in 1784.

I have reserved to the last that which is perhaps the most remarkable, as certainly it is the most erratic, of all the prominent variable stars—η Argûs. Unfortunately it is not visible

in the Northern hemisphere. Halley, on his return from St. Helena, as far back as 1677, frequently expressed doubts as to the constancy of the light of the stars in Argo. Though he seems only to have based his conclusions upon Ptolemy's statements of star magnitudes, yet these were generally so accurate that when discrepancies were found to exist between modern and ancient records the idea at once suggested itself that there had been actual change rather than mistakes of observation. Halley, in 1677, rated η Argûs as of the 4th magnitude. In 1751 La Caille noted it as of the 2nd magnitude. In the next half century it diminished, for Burchell, during his residence and travels in South Africa, between 1811 and 1815, saw it as of the 4th magnitude. Fallows, in 1822, at the Cape, and Sir T. M. Brisbane, between 1822 and 1826, in New South Wales, saw it as of the 2nd magnitude. In the following year, that is, on Feb. 1, 1827, Burchell, then at St. Paul's, in Brazil, saw it as of the 1st magnitude, and almost as bright as α Crucis; but within a year, that is, by Feb. 20, 1828, it had decreased to the 2nd magnitude, and as such was entered by M. J. Johnson and Taylor in their respective catalogues between 1829 and 1833. Sir John Herschel, who started observations at the Cape in 1834, found it then and for several years afterwards to be something between mags. 1 and 2 but nearer 2. It seems to have remained stationary, or nearly so, for well-nigh 3 years, but on December 16, 1837, on resuming work after an interval, Sir John was startled to find it had become one of the very

brightest stars of the 1st magnitude, excelling all belonging to that category except Sirius and Canopus. Sir John Herschel's account of it will bear quoting:—"Its light was nearly tripled. . . . It very decidedly surpassed Procyon, which was about the same altitude, and was far superior to Aldebaran. It exceeded α Orionis, and the only star (Sirius and Canopus excepted) which could at all be compared with it was Rigel, which it somewhat surpassed. From this time its light continued to increase. On December 28 it was far superior to Rigel and could only be compared with α Centauri, which it equalled, having the advantage of altitude, but fell somewhat short of it as the altitudes approached equality. The maximum of brightness seems to have been obtained [attained] about January 2, 1838, on which night both stars being high and the sky clear and pure, it was judged to be very nearly matched indeed with α Centauri, sometimes the one, sometimes the other, being judged brighter, but on the whole α was considered to have some little superiority. After this the light began to fade." Sir John then goes on to narrate the incidents of the declension of the star's light. His own observations ceased in April, 1838, but the star even then remained bright enough to be compared with Aldebaran. From other sources we learn that the diminution of light went on for 5 years, but that even in March, 1843, the star's lustre continued equal to that of an ordinary 1st magnitude star. At about that time a new outburst took place, and according to the observations of Mackey at

Calcutta, and Maclear at the Cape, η Argûs surpassed Canopus and scarcely fell short of Sirius in brilliancy. This lasted more or less through 1844, when a decline in its brilliancy set in. This proceeded, however, very slowly, because in February, 1850, Lieut. Gilliss, then in Chili, reported η Argûs as being nearly as bright as Canopus but of a reddish yellow colour, somewhat darker than Mars. In 1856 it was still of the 1st mag., but a steady decline was evidently in progress. Hence we find that in 1858 it was rated at mag. $2\frac{1}{2}$ by Powell; in 1860 at mag. 3 by Tebbutt; in 1861 at mag. $4\frac{1}{4}$ by Abbott; in 1863 at mag. 5 by Ellery; in 1867 at mag. 6 by Tebbutt. During the next 10 years it fell to mag. 7, and in March, 1886, was rated at mag. $7\frac{1}{2}$ by Finlay at the Cape of Good Hope. This appears to have been the lowest point, for by May, 1888, the light had increased by fully half a magnitude, so that apparently it is on its way towards another maximum, which perhaps may be expected within the first decade of the 20th century. From the foregoing account it is, however, clear that we do not possess sufficient information to assign with any reasonable degree of accuracy a period to η Argûs, though Wolf has suggested 46 years, and Loomis 67 years. Schönfeld, however, thinks that the star has no regular period at all. At any rate the maximum stage seems very complicated and to consist of 3 maxima which jointly occupy 25 years of the period whatever that may be. During this sub-period, the changes may perhaps be regarded as restricted

to the 1st and 2nd magnitudes, and this sub-period may perhaps be assumed to fall something like in the mid-interval between every 6th or 7th magnitude minimum of the star.

η Argûs is in the field with the celebrated "Great Nebula in Argo," and some remarkable circumstances bearing alike on the star and on the nebula will come under consideration in a later chapter in which the nebula will be described.

The reader who has followed me thus far in trying to pick up some ideas about the peculiarities of the stars called "variable" will very likely wish now to put the question, "What is a variable star?" It is impossible to answer such an inquiry with any confidence. It seems, however, likely that the variability of the stars which are known to be variable may be due to one of two causes, one of which applies to one class of star and the other to another class. It is generally accepted by astronomers that Algol is a type of a small number of stars which owe their peculiarity to a cause quite different from that which applies to the vast majority of these objects. The idea was started by Pigott in 1783, and has met with much acceptance that the periodical fluctuations in the light of Algol are due to the revolution round it of an opaque satellite smaller than itself yet large enough to eclipse partially the primary. With respect to the general run of variables it is thought that we may draw some inferences respecting them from what we know of the physical constitution of the sun and of what happens in or upon that

luminary. Now we know that from time to time, and according to a period which is recognised to amount to about 11 years, dark spots of various sizes and shapes and of different depths of shade break out upon the sun. The solar spots which we are accustomed to see, even the very largest of them, are too small relatively to the size and brilliancy of the sun to cause any measurable depreciation in the aggregate of the sun's light, but let us suppose it were otherwise, and that every 11 years masses of spots so extensive as to represent one-half or even one-fourth of the apparent surface of the sun, burst forth, we should then have the great centre of our system converted from a permanently bright star into a variable star. I speak of our sun as a bright star because probably it represents for us on the earth neither less nor more than what Sirius or other bright stars * represent to the inhabitants of other worlds in far-off regions of space. If we could travel from the earth a long way towards Sirius we should probably find Sirius to grow into what we should without reservation call a sun, whilst our sun would deteriorate into what we now call a star.

So much for the possible circumstances of those stars which undergo periodic changes of light. But this explanation, even if accepted so far, does not meet the case of those temporary outbursts of stellar light which we considered in Chapter XI. (*ante*). Here again, however, solar

* See p. 69 (*ante*).

history may be brought in. It is now quite recognised as a fact that the red flames seen during total eclipses of the sun are outbursts of glowing hydrogen gas emanating from the interior of the sun; nay more, that such emanations of burning hydrogen are constantly occurring on the sun. Now in the case of the temporary star in Corona Borealis which became visible in 1866, Huggins's observations tended to show that there happened in that star a sudden and extraordinary outburst of glowing hydrogen, which by its own light, as well perhaps as by heating up the whole surface of the star, caused the unwonted increase in its brilliancy which then took place. These ideas find confirmation in other directions, but it seems hardly within the design of this work to go further into details of this character.

There are, however, some miscellaneous facts connected with variable stars which are too interesting to be passed over. For instance, it is an undoubted fact that the vast majority of the variable stars are red or reddish in colour; and so general is this rule that whenever a new star is found it is a safe presumption to start with that if its colour is red it has hitherto escaped observation because of its being variable. Hind has noticed that variable stars when at minimum often appear hazy or foggy, on which Arago suggested the idea that the diminution of brilliancy might be due to the interference of clouds. It is an undoubted fact that in the case of red variable stars as they diminish in brilliancy they deepen in colour,

whilst as their light increases their hue becomes paler.

An experienced American observer, Chandler, has evolved a connection between the colours and periods of variable stars. He not only subscribes to the opinion that variable stars are generally red, but he finds that the more red they are the longer their periods. Of 112 variables whose colours and periods are fairly well established, classifying them in groups having periods of under 100 days, of 100 days but under 200, and so on up to over 400, he finds that whilst of those under 100 days barely one-half are red, of those over 100 days three-fourths are red; whilst those over 400 days are all red. His statistics arranged in another form show that whilst the periods of the white and yellow stars average 125 days, the periods of the red stars average 288 days, and of the intense red 77 days.

Espin has arrived at some curious statistics concerning the distribution of variable stars in the heavens, and also concerning their periods. He finds that they are especially numerous in a zone of the heavens inclined 15° or 20° to the equator; that this zone crosses the preceding side of the Milky Way on the N. side of the equator, and the following side of the Milky Way on the S. side of the equator; that the northern portion of the zone is not many degrees broad and is clearly marked, but that the southern portion is split into 2 streams of stars and that the place where this occurs is near the place where the Milky Way is also divided; that hereabouts the

variables seem connected with the Milky Way, often occurring in the gaps and constantly on the edges of the gaps, but rarely in the centre of the star sprays from the Milky Way; whilst the northern stream of variable stars is sharply defined by itself and seems unconnected with the Milky Way. Espin adds that with one or two exceptions all the temporary stars have appeared in the region where the Milky Way and the variable star zone are both broken into two streams; and that stars which do not belong to the above-named zone are chiefly the bright and short-period variables. Espin's statistics in detail are too elaborate for embodiment in these pages in their entirety, but some further general conclusions are of sufficient interest and importance to be reproduced. Writing in 1882 he found that the variables then known readily fell into two classes: (1) those with periods of less than 70 days; and (2) those with periods of more than 135 days; there being none with periods between 71 and 135 days. Of the former group it might be said that they were in colour white or red in tolerably even numbers, and large in magnitude; whilst the latter group were mainly red and small in magnitude.

Some other conclusions which he arrived at were that if the variation of light be small in extent, or if the star be bright, the period will probably be short; on the other hand, where the period ranges from 135 days up to 420 days the number of stars increases with the length of the period; also, that between a range of 1 magnitude up to 6 magnitudes the number of stars

increases with the variation in magnitude. These rules seem, however, to fail where the stars have periods of more than 420 days, or where the range extends beyond 6 magnitudes.

The foregoing statistics are based upon only a minority of the known variables, and therefore cannot yet be put forward as disclosing a series of general laws. Nevertheless, they are sufficiently interesting and pronounced to deserve attention now, as well as to encourage further inquiry in the future.

The following classification of variable stars has met with some acceptance in America, and therefore it may be given here, but it is open to the objection that it assumes that temporary stars are merely long-period variables, which at present is, at the best, an assumption :—

(1) Stars showing slow continuous change.
(2) Stars exhibiting irregular fluctuations of light: alternately brightening up and becoming dim without any apparent law.
(3) Temporary stars, which blaze out suddenly and then disappear.
(4) Periodic stars of the type of o Ceti, usually of long period.
(5) Periodic stars of the type of β Lyræ, of short period.
(6) Periodic stars of the type of Algol, in which the variation of light is such as would result from some intervening eclipsing the primary star.

It is evident from all that has gone before that variable stars form a very interesting branch of observational astronomy.

CHAPTER XIII.

THE STARS IN POETRY.

As the previous chapter concludes what I have to say respecting the stars taken individually, and the remainder of this volume will be occupied with the stars in masses under the designations Clusters and Nebulæ, the present seems a convenient point at which to withdraw the reader's thoughts for a while from the technicalities of science to things more light and sentimental. Hence it has occurred to me to try and enliven my pages by a few citations from English classical poetry—a field which has been worked with great assiduity, from an astronomer's standpoint, by Mr. J. E. Gore.*

Shakespeare of course occupies the front rank amongst the great English writers who have brought the facts of science, astronomical and general, into line with their ordinary musings. Unfortunately he lived at a period when the so-called science of astrology flourished side by side with astronomy, and trading as it did on the credulity of man it overshadowed but too successfully the sister science of astronomy, if such a bracketing together of fraud and humbug with true learning can be tolerated.

* In his *Scenery of the Heavens.*

Perhaps, after all, we of the 19th century must not be too hard on our forefathers of the Elizabethan epoch, for figures of speech implying a belief in the tenets of astrology and in many other ridiculous beliefs and practices hold sway in these closing years of the century, and they are not restricted to ignorant and unlettered dwellers in remote agricultural villages.

And now to Shakespeare. In *Julius Cæsar* (Act i., scene 2) Cassius says—

> "Men at some times are masters of their fates;
> The fault, dear Brutus, is not in our stars
> But in ourselves, that we are underlings."

The idea that the stars exercise some influence, for weal or woe, over the birth of individuals was widely prevalent 300 years ago, and Shakespeare does no more than conform to the ideas of the times when he makes Richard III. say (Act iv., scene 4)—

> "Lo, at their births good stars were opposite;"

or Jupiter, in *Cymbeline*, say (Act v., scene 4)—

> "Our Jovial star reign'd at his birth;"

whilst Romeo (Act v., scene 3) speaks in the Churchyard scene of shaking—

> "The yoke of inauspicious stars."

Malvolio, in *Twelfth Night* (Act ii., scene 5), expresses the popular sentiment in words most clear—

> "In my stars I am above thee; but be not afraid of greatness;"

and then follow immediately the familiar senti ments—

> "Some are born great, some achieve greatness, and some have greatness thrust upon them."

Particular constellations or groups of stars are occasionally referred to by Shakespeare. Thus in *Othello* (Act ii., scene 1) the sea, stirred by the wind, is said to—

> "Seem to cast water on the burning Bear,
> And quench the Guards of the ever-fixed Pole."

What idea underlies the application of the term "burning" to Ursa Major does not appear.

The Pole Star receives elaborate treatment in *Julius Cæsar* (Act iii., scene 1). Cæsar himself thus speaks—

> "But I am constant as the northern star,
> Of whose true-fix'd, and resting quality
> There is no fellow in the firmament.
> The skies are painted with unnumber'd sparks,
> They are all fire, and every one doth shine;
> But there's but one in all doth hold his place."

In the letter read by Polonius (*Hamlet*, Act ii., scene 2) we come upon an idea which is alike ancient (for Stoics and Epicureans held it) and modern—

> "Doubt thou the stars are fire:
> Doubt that the sun doth move."

Milton is another of our great national writers who makes various allusions to celestial objects.

In the *Paradise Lost* (Book vii.) he refers to the moon and stars—

> ". . . then formed the moon
> Globose, and every magnitude of stars,
> And sowed with stars the heavens, thick as a field ;"

and to the Pleiades (in the same book)—

> ". . . the gray
> Dawn, and the Pleiades, before him danced,
> Shedding sweet influence."

Young's *Night Thoughts* is peculiarly rich in its references to astronomy. Perhaps the best-known passage of all is that in the "9th Night," which runs as follows :—

> "Devotion ! Daughter of Astronomy,
> An undevout Astronomer is mad.
> True ; All Things speak a God ; but in the Small
> Men trace out Him ; in Great He seizes Man."

In the following passage ("8th Night") we come upon the idea already mentioned in these pages as being a sober astronomical probability—

> "These sparks of night, these stars shall shine,
> Unnumber'd Suns."

Again, the following passage referring to the distances of the stars contains, as we have seen, true astronomical teaching—

> "How distant some of these nocturnal Suns !
> So distant (says the Sage) 'twere not absurd
> To doubt, if Beams set out at Nature's Birth,
> Are yet arrived at this so foreign World
> Tho' nothing half so rapid as their Flight."

Truly indeed may it be said that the stars serve the purpose thus suggested by Young—

"One Sun by Day, by Night ten thousand shine
And light us deep into the Deity."

In Byron's *Childe Harold's Pilgrimage* (Canto III., v. lxxxviii.) we find the following striking passage:—

"Ye stars! which are the poetry of heaven!
If in your bright leaves we would read the fate
Of men and empires—'tis to be forgiven
That in our aspirations to be great,
Our destinies o'erleap their mortal state
And claim a kindred with you; for ye are
A beauty and a mystery, and create
In us such love and reverence from afar,
That fortune, fame, power, life, have named themselves a star."

Shelley in his *Prometheus Unbound* (Act iv.), speaking of an astronomer in his observatory, says—

"Heaven's utmost deep
Gives up her stars, and like a flock of sheep
They pass before his eye, are number'd, and roll on."

Moore in his *Light of the Haram* thus brings in the Pole Star—

"Whose light, among so many lights,
Was like that star, on starry nights
The seaman singles from the sky,
To steer his bark for ever by!"

Elsewhere (*Sacred Songs*) he makes a further allusion to the Pole Star—

"As still to the star of its worship, though clouded,
The needle points faithfully o'er the dim sea."

By the way, this allusion is not scientifically accurate, for the compass-needle does not point to the Pole Star, but to the earth's magnetic pole.

The stars naturally find a place in Thomson's *Seasons*. He says—

> "Snatch me to heaven; thy rolling wonders there,
> World beyond world, in infinite extent,
> Profusely scatter'd o'er the blue immense,
> Show me: their motions, periods, and their laws,
> Give me to scan."

Longfellow remarks—

> "Wondrous truths, and manifold as wondrous,
> God hath written in those stars above."

Wordsworth, in *The Excursion* (Book IV.) thus brings in the uses of the Pole Star—

> "Chaldean shepherds, ranging trackless fields,
> Beneath the concave of unclouded skies
> Spread like a sea, in boundless solitude
> Looked on the polar star, as on a guide
> And guardian of their course, that never closed
> His steadfast eye."

And in *Poems of the Imagination* (Part II., xxv.)—

> "The stars are mansions built by Nature's hand,
> And, haply, there the spirits of the blest
> Dwell clothed in radiance, their immortal vest."

Tennyson is very astronomical. In *The Princess* we find—

> "And the shining daffodil dies, and the Charioteer
> And starry Gemini hang like glorious crowns
> Over Orion's grave low down in the west."

Tennyson has a very good conception of a binary star when he speaks of—

> "those double stars
> Whereof the one more bright
> Is circled by the other."

CHAPTER XIV.

GROUPS OF STARS.

THE thing to do in order to be able to realise to the utmost the marvellous beauty of the starry heavens, is to obtain an opportunity of gazing at some of those crowded fields of stars bordering on the Milky Way, in which the stars are so close together that though they hardly constitute a "cluster" technically so-called, are yet so numerous that the whole circular field of the telescope is one shining mass of bright points. There is such a field, favourably circumstanced for observers in England in the constellation Perseus (R.A. 2h. 11m. 20s. Decl. + 56° 38′), and I would urge every reader of this book to take the first opportunity open to him of viewing this in a telescope of, if possible, not less than 3 inches aperture. Doing this he will, I am confident, be more inspired to dedicate to astronomy some of his time, thoughts, and money, than by doing anything else which I could suggest. This particular object is sometimes called "The Cluster in the Sword Handle of Perseus."

Starting with the stars as single stars we have

seen that a considerable number go together in pairs; that a smaller number are associated in triplets; and so on, till we come to a principal star having, it may be, half a dozen companions gathered round it. The transition from such a group to what is called a "cluster," and so on to a "resolvable nebula," is a gradual one which, however, may be said to come about in the nature of things almost as a matter of course. The lines of demarcation between these different classes of objects are naturally not very pronounced, and must be laid down in a rather arbitrary manner. However, I think that for our present purpose we may conveniently range the celestial objects now about to be described under the three following heads:—(1) Irregular groups more or less visible to the naked eye; (2) Clusters of stars resolvable into their constituent stars, with the aid of a telescope; (3) Nebulæ for the most part irresolvable with the telescopes we at present possess; either because the telescopes are deficient in the necessary optical power, or because the objects themselves are not stellar at all, but are something else—gaseous or what not.

Of the groups of stars which may be considered to be incipient clusters there are several visible to the naked eye, not counting certain true nebulæ which can be detected by the naked eye by reason of their great size. Three of these clusters were noticed and recorded by the ancients, namely, the "Pleiades" and "Hyades" in Taurus, and "Præsepe" in Cancer. The Pleiades are mentioned twice in the Book of

Job, and once in the prophecy of Amos, and also in Homer, who likewise names the Hyades. The passages in Job and Amos have already been quoted.* The passage in Homer *(Odyssey* Lib. v. ver. 270) runs thus in Pope's version :—

> "With beating heart Ulysses spreads his sails;
> Plac'd at the helm he sat, and mark'd the skies,
> Nor clos'd in sleep his ever-watchful eyes.
> There view'd the Pleiads, and the northern team,
> And great Orion's more refulgent beam,
> To which, around the axle of the sky
> The bear revolving, points his golden eye."

The Pleiades were always supposed to be 7 in number; then one was said to have disappeared, so that 6 only remained. This transaction appears to be lost in obscurity; I had even said is unhistoric. Yet Ovid has recorded it in the famous line :—

> "Quæ *Septem* dici, *sex* tamen esse solent."

However, whilst ordinary eyes can, as a rule, only grasp 6 stars, the 7th is still there, and can be seen with the slightest optical help; whilst very good eyes can make out several more. Miss Airy, indeed, has noted 12. With a small telescope any number (say at least 50) may be seen, and photography has recorded over 2000 stars. The brightest in the group is Alcyone, otherwise η Tauri, of the 3rd magnitude; next in order come Electra and Atlas, both $3\frac{3}{4}$, Maia 4, Merope $4\frac{1}{4}$, Taygeta $4\frac{1}{2}$; whilst Celeno, Asterope, and Pleione are all smaller and of much the same brightness, say mag. 6. Then follows a miscellaneous crowd of smaller stars.

* *Ante*, p. 46.

A passing allusion must be made to certain modern discoveries connected with the Pleiades,

FIG. 12.—THE PLEIADES.

the exact import of which is at present very imperfectly understood. On October 19, 1859, Tempel, a German observer resident in Italy,

observed an object which he took to be a telescopic comet. On the following evening he found it in the same position, and therefore not a moving comet, but a stationary nebula. It was seen subsequently by other observers. Auwers noted it to be about $\frac{1}{4}^{\circ}$ in extent, but thought that it might have escaped notice owing to its proximity to Merope, one of the Pleiades, the bright light of which would overshadow the nebula. Schiaparelli in 1875 saw the nebula very clearly, and was much surprised at its size and apparent ramifications in different directions. Hind had stated that he had often suspected nebulosity around some of the smaller outlying stars of the Pleiades. The earlier observations of this nebula (or these nebulæ) in the Pleiades were by no means very consistent, and the idea of variability suggested itself; some even regarded the whole thing as a myth. But later researches by the aid of photography have not only established the reality of Tempel's discovery, but have done a good deal more; for it is now certain that no fewer than five of the chief stars in the Pleiades (Pleione, Atlas, Asterope, and Taygeta being the exceptions) are involved in a mass of nebulous matter, the extent of which was never suspected until the photographic proof was obtained at Paris in 1885. It is satisfactory, under the circumstances, to know that a general confirmation of the photograph has been obtained by the direct testimony of the telescope in the shape of eye-views at the Russian observatory at Pulkowa, with the gigantic refractor of 30 inches aperture there in use.

The Hyades form a more open and less interesting group, also in the constellation Taurus, and near Aldebaran; but the stars are too scattered to make a very striking field.

Præsepe in Cancer is altogether a more effective group; one, however, which should be looked at through a telescope with a low power and large field. This object, long called the "Bee-hive," appears to have been the first object to which the term "nebula" was applied in bygone days, its component stars not being separately distinguishable. We have it on record that Præsepe was taken account of by the ancients 2000 years ago; for both Aratus and Theophrastus tell us that its dimness and disappearance during the progressive condensation of the atmosphere were regarded as the first sign of approaching rain. Galileo with his baby telescope counted 36 stars. To find Præsepe, carry an imaginary line from Spica Virginis under Regulus in Leo, and about 22° beyond it will strike Præsepe.

The group of stars forming the constellation Coma Berenices is cited by Webb as "a gathering of small stars which obviously at a sufficient distance would become a nebula to the naked eye." By the way, this constellation is said to have been instituted by the astronomer Conon in honour of the Queen of Ptolemy Soter, who dedicated her splendid tresses to the gods to secure her husband's safety in war!

CHAPTER XV.

CLUSTERS OF STARS.

We have now to consider the clusters of stars which, though seemingly nebulous in very small telescopes, become immediately resolved into individual stars on the application of a very slight additional amount of optical power. A select number of these are put together in the Appendix for the use of those readers of this book who, possessing telescopes, would wish to know whither to direct them profitably. It will suffice, therefore, to allude here to only a few of these clusters. 31 ♅ VI. Cassiopeiæ is a somewhat conspicuous object and readily seen with a telescope of 2 inches aperture. Perhaps the best known of all the so-called globular clusters is 13 M. Herculis, that is to say, the 13th in Messier's Catalogue and in the constellation Hercules. This is commonly regarded as the finest of the globular clusters. Smyth called it "an extensive and magnificent mass of stars with the most compressed part densely compacted and wedged together under unknown laws of aggregation." Sir J. Herschel spoke of its thousands of stars and "hairy-looking curvilinear branches," which features the Earl of Rosse interpreted as indicative of a spiral tendency; he also perceived several dark rifts in the cluster. Beautiful as it is—one might even say magnificent—yet J. P. Nichol goes a little too far in asserting that "perhaps no one

ever saw it for the first time through a telescope without uttering a shout of wonder."

Before offering any further remarks on the larger clusters it will be convenient to explain the word "globular," and seemly to say something about the French astronomer Messier, whose name is so closely associated with these objects. "Globular," as a word, of course needs

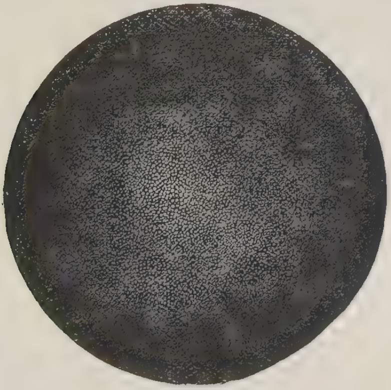

FIG. 13.—13 M. HERCULIS.

no explanation, but it was first applied to star clusters, I believe, by Sir W. Herschel, in order to convey to the mind the idea that, when looking at them, the eye is gazing not on a flat background sprinkled with stars, but on a veritable ball of stars. Without saying that all or even any of the clusters so called are truly such, yet undoubtedly an ordinary eye will readily appreciate them as balls of stars.

Messier was a Frenchman who dedicated himself about a century ago to the task of hunting for comets. In carrying out this work he was so far very successful that between 1760 and 1798 he found no fewer than 13. He was, however, much bothered by constantly coming upon objects in his small telescope which, whilst they looked at first like comets, were only clusters and nebulæ; so in 1758 he thought to guard against being taken in any more by forming a permanent catalogue of nebulæ, including clusters, by collecting together all that had been found by himself, La Caille, and Méchain. This catalogue was published (but whether for the first time or not I am not sure) in 1784, and is alike a monument of its author's shrewdness and of his industry, for it embraces, with scarcely an exception, the whole of the conspicuous clusters and nebulæ visible in the latitude of Paris.

We will now resume our consideration of the clusters by mentioning a few more of them. Next after the cluster in Hercules comes perhaps 5 M. Libræ, which, in the words of Webb, is a "beautiful assemblage of minute stars greatly compressed in the centre." Sir W. Herschel with his 40-ft. reflector made out about 200 stars, though the middle of it was so compressed that it was impossible to individualise the components. Smyth says that:—"This superb object is a noble mass, refreshing to the senses after searching for faint objects, with outliers in all directions and a bright central blaze." Messier, however, "assured

himself that it did not contain a single star," but this unsound statement was the unwise result of dogmatising, on the strength of a telescope 2 feet long.

80 M. Scorpii is a compressed globular cluster which Messier, who found it in 1780, described as resembling the nucleus of a comet; and indeed

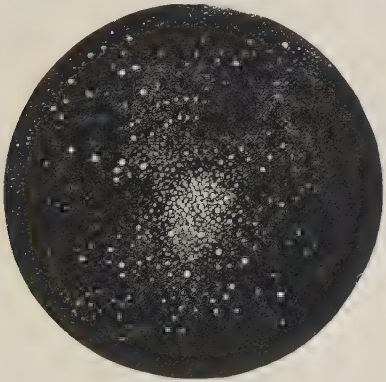

FIG. 14.—5 M. LIBRA.

its blazing centre and attenuated disc give it a very cometary aspect. Sir W. Herschel pronounced it to be the richest and most condensed mass of stars which the firmament can offer to the contemplation of astronomers, albeit that Messier had registered it as *Nébuleuse sans étoiles*. Near the centre of this object, or, as Webb suggested, "between it and us," there burst forth in 1860 a remarkable temporary star. Pogson had been familiar with the cluster

because two variable stars, R and S Scorpii, were in the field with it, and he had frequently been in the habit of viewing them. On May 28, 1860, while seeking for these variables, his attention was arrested by the fact that a star of about the 7th magnitude had appeared in the place previously occupied by the cluster. He had seen the cluster as recently as May 9,

FIG. 15—80 M. SCORPII.

and was positive that it had appeared exactly the same as usual without anything stellar about it. The same instrument and power had been employed on both occasions. A fortnight later, that is, on June 10, using a lower power, the stellar appearance had nearly vanished, but the cluster still shone with unusual brilliancy and a marked central condensation. Pogson's observations were fully confirmed by two German observers, E. Luther and Auwers. Pogson thus

summed up the circumstances of this curious case:—"It is therefore incontestably proved upon the evidence of 3 witnesses that between May 9 and June 10 [1860] the cluster known as 80 Messier changed apparently from a pale cometary-looking object to a well-defined star fully of the 7th magnitude, and then returned to its usual and original appearance. It seems to me absurd to attribute this phenomena to actual change in the cluster itself, but it is very strange if a new variable star, the 3rd in the same field of view, should be situated between us and the centre of the cluster." At the time when this was written the incident thus narrated was unique, but the more recent case of Nova Andromedæ appears to present various analogies to the case of 80 M. Scorpii in 1860. Schönfeld thought he saw some trace of the star in June, 1869, but, barring this, I am not aware of any further information being on record. There are many other globular clusters to be met with in the heavens, some which will be found referred to in the List in the Appendix, but 2 more only need be mentioned here. These are both in the southern hemisphere, and surpass, it would seem in the matter of size and brilliancy, anything visible in England.

47 Toucani was described by Sir J Herschel as a superb globular cluster "very visible to the naked eye and one of the finest objects in the heavens. It consists of a very condensed spherical mass of stars of a pale rose-colour concentrically enclosed in a much less condensed globe of white ones 15′ or 20′ in

diameter." Herschel, in speaking of this cluster, made the very curious and significant remark that he could not remember a single elliptical nebula which is resolvable, all the resolvable clusters being more or less circular in form. He then goes on to add :—"Between these two characters then (ellipticity of form and difficulty of resolution) there undoubtedly exists some physical connection . . . it deserves also to be noticed that in very elliptic nebulæ which have a spherical centre (as in 65 M.) a resolvable or mottled character often distinguishes the central portion, while the branches exhibit nothing of the kind." This was written prior to the construction of Lord Rosse's great telescope, and therefore it is no reflection on Sir John's accuracy to point out that the "Crab Nebula" in Taurus is an exception to the above rule.

Respecting the cluster surrounding ω Centauri, Sir John Herschel says that "it is visible to the naked eye as a dim, round, cometic object about equal to a star of 4½ magnitude, though probably if concentrated in a single point the impression on the eye would be much greater. Viewed in a powerful telescope it appears as a globe of fully 20′ in diameter, very gradually increasing in brightness to the centre, and composed of innumerable stars of the 13th and 15th magnitudes, the former probably being two or more of the latter closely juxtaposed."

This chapter may appropriately be concluded with a mention of some large clusters not specifically globular in form. 67 M. Cancri is a rich

but loose cluster at the root of the Crab's southern claw. Smyth noted it as consisting principally of a mass of stars of the 9th and 10th magnitudes, gathered somewhat in the form of a Phrygian cap, followed by a crescent of stragglers. W. Herschel saw above 200 stars at

FIG. 16.—67 M. CANCRI.

once in the field of view. This object precedes α Cancri by about 2°.

77 M. Ceti is a round stellar object near ζ in the constellation named. It is small, bright, and exactly in a line with 3 small stars, one preceding and 2 following; of which the nearest and largest is of the 9th magnitude. Sir W. Herschel made this object a peg on which to

hang the following remark:—"We may conclude that the profundity of the nearest part is at least of the 910th order." By this Sir William meant that this object is 910 times as far off as stars of the first magnitude; but, to say the least of it, this is a highly imaginative thought

FIG. 17.—77 M. CETI (NEBULOUS STAR).

—one of a type which I think is too common—and rather apt to make astronomy and astronomers look ridiculous in the minds of matter-of-fact people.

The cluster 11 M. Antinoï is an interesting cluster of uncommon form. Smyth likened it to a flight of wild ducks, a simile more appropriate than many of those met with in astronomical writings. There is an 8th magnitude

star in the middle, and two outside its limits and preceding it. Smyth remarks:—"By all analogy these are decidedly between us and the cluster." This, however, was not the opinion of Kirch, its discoverer, who, in 1681, described it as a small, obscure spot, with a star shining *through* and rendering it more luminous.

In the field with, and adjacent to, the star κ Crucis there is a large and loose cluster, described by Sir John Herschel as one of the most beautiful objects of its class. It comprises more than 100 stars from the 7th magnitude downwards, 8 of the more conspicuous of them being coloured various shades of red, green, and blue. This object was very carefully surveyed in 1872 by Russell at Sydney, who remarked that many of the stars had drifted (presumably in consequence of proper motion) in the 40 years which had elapsed since Sir John's drawing was made. Russell adds:—"The colours of this cluster are very beautiful, and fully justify Herschel's remark that it looks like a 'superb piece of fancy jewellery.'"

CHAPTER XVI.

NEBULÆ.

In the present chapter we shall consider the Nebulæ commonly so called—those celestial objects of very diverse sizes, shapes, and brilliancy, of which many or most are probably stellar in their constitution, though some of

them, however, may be not such but gaseous. At the outset I will deal with them merely descriptively. Messier's catalogue, to which such frequent allusions have been made, embracing as it did only those larger and brighter objects which were within reach of a mere hand telescope, does in no way indicate the present state of our knowledge respecting the nebulæ. The bulk of the objects enrolled by Messier eventually proved to be resolvable star clusters, though a residue were veritable nebulæ—faint, misty objects, many of them not unlike specks of luminous fog. Of these nebulæ some have yielded to the larger telescopes of modern days, and have proved to be masses of stars too closely aggregated together to be resolved by the puny telescopes which only were available a century or more ago. Since Messier's days, and as a result of so many large telescopes having been set to work during the second half of the nineteenth century, the number of observed nebulæ has become so great that upwards of 8000 are now on record. By far the greater number of these are, however, irresolvable, and therefore it is an open question what they are.

The nebulæ generally may be conveniently classified under six general heads, it being understood of course that this classification only has regard to form or size:—(1) Annular nebulæ; (2) elliptic nebulæ; (3) spiral nebulæ; (4) planetary nebulæ; (5) nebulous stars; (6) large nebulæ of irregular form.

The annular nebulæ hitherto recognised scarcely number a dozen, and of these one only

is large or bright enough to have obtained much notoriety. This is Messier's 57th in the constellation Lyra. If it be realised that the word "annular" is derived from the Latin word *annulus*, a ring, a ready clue will be had as to the general form of these bodies. The annexed engraving indicates it, but only that simple conception which is obtainable by means of a moderate-sized telescope—say an instrument of

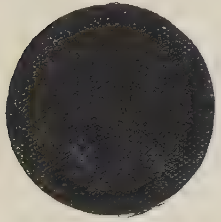

FIG. 18.—THE RING NEBULA IN LYRA. (*Sir J. Herschel.*)

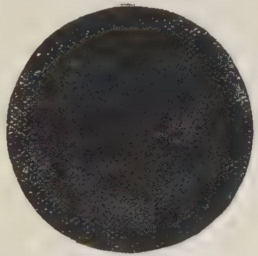

FIG. 19.—THE RING NEBULA IN LYRA. (*Earl of Rosse.*)

4 inches aperture. With instruments of much larger size the individuality of the ring disappears, and the central space, black or nearly so in a small telescope, shows evident indications of nebulous matter, which Lord Rosse found to be distributed, not uniformly, but in streaks; whilst the external edge of the ring was broken by projections of various sizes and shapes. All these particulars will be better understood from a picture than from any written description. There is considerable conflict of opinion as to the ultimate account which ought

to be rendered of this object when the largest available telescopes are brought to bear upon it; Rosse, Chacornac, and Secchi all claimed to have resolved it into stars. Huggins, on the other hand, insists that it is merely a mass of glowing gas. The Lick observers find its structure to be very complex, but seem unwilling to commit themselves to a very definite opinion on the subject. At the same time they make mention of the existence of, and describe the position of, numerous individual stars.

Elliptic nebulæ of various degrees of eccentricity, from a common oval to a long streak, are met with in various parts of the heavens. As a rule they are very bright, and several of them are remarkable as having double stars at or near each of their foci. There is one elliptic nebula which stands out beyond all the rest, yet its great size, brilliancy, and peculiar features forbid its being regarded as a typical elliptic nebulæ. I am here alluding to the "Great Nebulæ in Andromeda," Messier's 31st. Its ellipticity is considerable; it is likewise very long, and has a bright central condensation which renders it readily discoverable by the naked eye on a clear night not far from the star η Andromeda of magnitude $4\frac{1}{2}$. Sir John Herschel's drawing is well known, having obtained wide circulation through his own and other people's books. G. P. Bond was the first to improve upon it, which he did when he published, more than 40 years ago, an engraving exhibiting much more internal detail than Herschel had shown. In particular two curious

black streaks or longitudinal vacuities, which run nearly parallel to the major axis of the oval on the south side. Bond traced the nebula to a length of 4° and a breadth of $2\frac{1}{4}$°.

Roberts (see Frontispiece) has carried the matter still further than Bond had done, for he finds traces of a dark ring separating the central parts of the nebula from an outer brighter portion, the whole yielding traces of what may indicate a spiral structure. No telescope has yet resolved this object distinctly into stars, though several hundred stars have been counted within its limits. This object is, however, probably stellar, and may one day be proved to be such; certain is it that it is not gaseous. The other extreme of elliptic nebula is illustrated in Fig. 20, which represents 43 ♅ I. Virginis, a long, narrow wisp of luminous matter with a slight condensation in the centre.

FIG. 20.—THE NEBULA 43 ♅ I. VIRGINIS.

"Spiral," or, as they are sometimes called, "Whirlpool" nebulæ first had that special feature of them brought out by the late Earl of Rosse. The best known is Messier's 51st in the constellation Canes Venatici. To Sir J. Herschel it presented the appearance of a bright globular cluster encompassed at some distance by a bright nebulous ring, which varied very much in brightness in its different parts. It seemed as if it was split through for about $\frac{2}{5}$ths of its circumference into 2 laminæ, one of which gave the impression that it was turned

up towards the eye, out of the general plane. Sir John saw, seemingly detached from the main object, a small, bright, round nebula. Lord Rosse's telescope entirely altered the aspect of the whole group. The ring was found to pass into a distinct spiral coil of nebulous matter,

FIG. 21.—THE SPIRAL NEBULA 51 M. CANUM VENATICORUM.
(*Sir J. Herschel.*)

and the outlying portion to be connected with the main mass by a curved band, the whole showing indications of resolvability into stars. No ordinary telescope affords even suspicion of these details. The spectrum appears to be non-gaseous, which may be the equivalent of saying that the nebula is truly stellar.

"Planetary" nebulæ are objects first so desig-

nated by Sir W. Herschel because they exhibited a fairly well defined outline as of a disc, circular or slightly oval, and in a sense resemble the

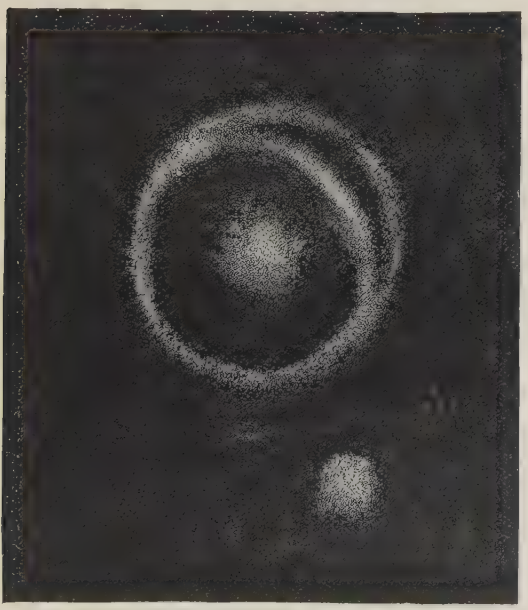

FIG. 22.—THE SPIRAL NEBULA 51 M. CANUM VENATICORUM. (*Earl of Rosse.*)

larger planets. The most striking of these is Messier's 97th in Ursa Major, 2° south and following the star β. It has been described as "a very singular object, circular and uniform,

and after a long inspection looks like a condensed mass of attenuated light." It has a diameter of 2′ 40″. The late Earl of Rosse detected perforations and a spiral tendency in it. He found a star in about the centre of each main perforation and called it the "Owl" nebula, from its appearance. One of the stars seems to have disappeared since 1850, or, as a thoughtful writer suggests, the owl has closed one of his eyes! Huggins has found the spectrum gaseous.

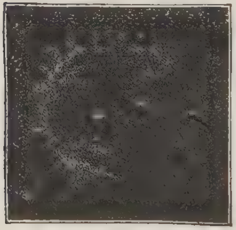

FIG. 23.—THE "OWL" NEBULA IN URSA MAJOR.

The planetary nebulæ are not very numerous and not very bright, which is a matter for regret, because it would seem that they possess interesting features entitling them to the special attention of astronomers but needing large telescopes. For instance, there is one in the constellation Draco, No. 37 in Sir W. Herschel's IVth class, which, according to Professor Holden, who has studied it with the Lick telescope, possesses an extraordinary structure. He says that it "is apparently composed of rings overlying each other, and it is difficult to resist the conviction that these are arranged in space in the form of a true helix." At the first glance the nebula appears to Holden to consist of 2 circles which intersect, a central star being within the area, resulting from the intersection of the 2 circles. At the S. point of intersection the brightness is approximately twice the aver-

age brightness of the circumference; at the N. point it is less bright relatively. A little attention, however, seems to show that these rings are so arranged that one complete ring lies on the upper or hither side (nearer the eye) of the other complete ring which is undermost or farther from the eye. There is another peculiar feature. The nebula itself is unmistakably blue in colour, whilst the star is yellowish-red. Star and nebula yield different spectra, and require for accurate definition the telescope to be brought to a different focus according as it is desired to obtain a good image of the one or the other. All these facts point to remarkable intrinsic peculiarities in this object. Holden finds the nebula 1 ♅ IV. Aquarii to possess some analogies with the nebula in Draco just described.

Before passing away from the planetary nebulæ some further peculiarities appertaining to them deserve a passing notice. According to the spectroscope, they are mostly gaseous, and several are noticeably bluish in hue. Three-fourths of them are in the southern hemisphere, and the greater number are in, or very close to, the Milky Way.

"Nebulous stars," according to their name, are ordinary stars with a faint nebulosity surrounding them; but the term does not seem altogether a happy one. Hind remarks that the nebulosity is in some cases well defined, but in other cases is quite the reverse; that "the stars thus attended have nothing in their appearance to distinguish them from others entirely destitute of such appendages; nor does the nebulous matter

in which they are situated offer the slightest indication of resolvability into stars with any telescopes hitherto constructed."

Perhaps the most striking nebulous star is No 45 in Sir W Herschel's IVth class, in the constellation Gemini. Sir John Herschel speaks of it as an 8th magnitude star which lies "exactly in the centre of an exactly round, bright atmosphere 25″ in diameter." Key described it as "a bright but somewhat nebulous star closely surrounded by a dark ring; this again by a luminous ring; then an interval much less luminous, and, finally, at some distance an exterior luminous ring." This description accords well with the late Earl of Rosse's.

The brightest nebulous star certainly recognised as such appears to be ι Orionis, a triple star of mag. 3½. ε Orionis of mag. 2½, is often spoken of as a star surrounded by a nebulosity, but the evidence is very contradictory, and inclines on the whole to the negative.

The last class of nebulæ remaining to be described are some of very diverse size and shape, which cannot be brought under any general denomination.

The "Crab nebula" in Taurus bears a popular and familiar designation, but it does not seem to rest on a very satisfactory foundation. In all ordinary telescopes this object exhibits a simple oval outline, but the special title was based on the late Lord Rosse's early description of it, which Sir John Herschel thought justified by the facts, though the later Parsonstown observations seem to negative the claw features. It was the

discovery of this object in 1758, when he was following a comet, which led Messier to form his well-known catalogue of nebulæ.

All things considered, it seems probable that the "Great Nebula in Orion" must be regarded as the grandest and most interesting of all the nebulæ. I have in a previous chapter mentioned it in connection with the multiple star θ Orionis, which it surrounds; and the diagram already given, rough though it is, affords an idea of the prominent feature of the nebula which presents itself in every small telescope, namely, the "Fish's mouth." Sir John Herschel's general description, written a great many years ago, still in the main holds good, though modern observations, when made with the large telescopes of the present day, bring out many features not recognised half a century ago; and in particular exhibit very distinctly what may be called the flocculent character or structure of the nebula.

Sir John Herschel's account runs as follows:—"In its more prominent details may be traced some slight resemblance to the wings of a bird. In the brightest portion are four conspicuous stars, forming a trapezium. The nebulosity in the immediate vicinity of these stars is flocculent and of a greenish-white tinge; about half a degree northward of the trapezium are 2 stars involved in a branching nebula of singular form, and southward is the star ι Orionis, also situated in a nebula. Careful examination with powerful telescopes has traced out a continuity of nebulous light between the great nebula and both these objects, and there can be but little doubt that

the nebulous region extends northwards as far as in ϵ the belt of Orion, which is involved in a strong nebulosity, as well as several smaller stars in the immediate neighbourhood."

Secchi thought that this nebula must be considered as extending far beyond the limits usually assigned to it, and that there exist in various directions, and remote from the principal centre, scattered fragments of nebulous matter which all really belong to the main mass. He ascribed to the whole, speaking roughly, a triangular outline with a base of 4° and a height of about 5½°, reaching downwards from ζ in Apex (with a break, however, at σ) almost as far as ϵ. Photographic and spectroscopic observations have been carried out on a considerable scale of late years. The latter are thought to indicate that the nebula consists of incandescent hydrogen gas. The multiplication of photographs spread over a term of years may lead to a better understanding of the circumstances and conditions of this nebula than is at present possible. The existing drawings of it, extending over nearly a century, are so much wanting in consistency one with another as to have led many persons to surmise that it has undergone distinct change but the evidence to support this theory falls far short of what is necessary to sustain such a suggestion.

30 Doradûs is a nebula in the Southern hemisphere which, from Sir John Herschel's description and engraving of it, must be a very remarkable object. Sir John speaks of it as "one of the most singular and extraordinary

objects which the heavens present.' Strange to say, he does not describe it in detail, contenting himself by saying that the engraving (in his *Outlines of Astronomy*) is so satisfactory as to render further description superfluous. The special feature of this nebula is the wonderful series of convolutions which it exhibits—masses of nebulous matter twisted in and out in singular fashion with numberless black, or more or less starless, interstices.

Another Southern nebula not entirely unlike the foregoing is that surrounding the strange variable star η Argus already described. Sir John Herschel's account of it, penned at the Cape of Good Hope some 60 years ago, runs as follows:—"Viewed with an 18-inch reflector, no part of this strange object shows any sign of resolution into stars, nor in the brightest and most condensed portion, adjacent to the singular oval vacancy in the middle of the figure, is there any of that curdled appearance, or that tendency to break up into bright knots with intervening darker portions, which characterise the nebula of Orion, and indicate its resolvability. . . . It is not easy for language to convey a full impression of the beauty and sublimity of the spectacle which this nebula offers, as it enters the field of the telescope (fixed in R.A.) by the diurnal motion, ushered in as it is by so glorious and innumerable a procession of stars, to which it forms a sort of climax."

Some mystery hangs over this nebula and its central star. Much excitement was caused in 1863 by the publication of an announcement by

Abbott, of Hobart Town, Tasmania, that, whereas Sir John Herschel had noticed near the centre of the nebula a lenticular sort of space devoid of stars, η being some distance from this void and closely encompassed by nebulous matter, the void space had altered in form, and the star (which had dwindled down to the 6th mag.) no longer had nebulous matter close up to it. These assertions, indicative, if true, of material changes in the appearance of the nebulæ having taken place between 1883 and 1863, were reviewed by Captain J. Herschel, in India, and Dr. B. A. Gould, in South America, and others, and the general verdict was that the allegations of Abbott were unfounded, and that Sir John Herschel's drawing of 1833 continued in 1882 to represent the details of the nebula as they were to be seen at the later date.

The constellation Sagittarius contains 2 large nebulous masses of considerable interest at no great distance from each other. 20 M. Sagittarii is the chief member of an important group respecting which Sir John Herschel writes as follows:—" One of them is singularly trifid, consisting of 3 bright and irregularly formed nebulous masses, graduating away insensibly externally, but coming up to a great intensity of light at their interior edges, where they enclose and surround a sort of three-forked rift or vacant area, abruptly and uncouthly crooked, and quite void of nebulous light. A beautiful triple star is situated precisely on the edge of one of these nebulous masses, just where the interior vacancy forks out into two channels."

8 M. Sagittarii, not far from the last named, is another remarkable object, perceptible to the naked eye, and showing effectively, even in a telescope as small as a 3-inch. Sir John Herschel thus speaks of it :—" A collection of nebulous folds and masses, surrounding and including a number of oval dark vacancies, and in one place coming up to so great a degree of

FIG. 24.—THE "OMEGA" NEBULA IN SCUTUM SOBIESKII.

brightness as to offer the appearance of an elongated nucleus. Superposed upon this nebula, and extending in one direction beyond its area, is a fine and rich cluster of scattered stars, which seem to have no connection with it as the nebula does not, as in the region of Orion, show any tendency to congregate about the stars."

The small constellation Scutum Sobieskii contains a rather famous object sometimes (but not very judiciously) called the "Horse-shoe" nebula, or by others (and with more propriety)

the "Omega" nebula. From the engraving annexed it will be seen that, as regards at any rate a small telescope, the idea conveyed is more that of a *swan* as seen floating on the surface of water. As in the case of η Argus, allegations have been made, and apparently with better foundation in this case, that important changes have taken place in the appearance of this nebula since the first drawings of it were made. Weighty names are attached to these conclusions, and Holden, who has investigated with much care and detail its history, as recorded between 1833 and 1875, concludes that "the 'Horse-shoe' has moved with reference to the stars," and that therefore "we have evidences of a change going on in the nebula. This may be a veritable change in the structure of the nebula itself, such as was suspected by Schröter, confirmed by O. Stuve, and again confirmed by myself in the nebula of Orion; or it may be the bodily shifting of the whole nebula in space."

The "Dumb-bell" Nebula (27 M. Vulpeculæ) is too well known to need a lengthened description in this place. The records of its appearance during more than a century past, as telescopes of successively increasing power have been brought to bear on it, constitute a weighty warning to those who, on the strength of seeming discrepancies in verbal descriptions and drawings, choose to infer that absolute changes have taken place in the appearance or circumstances of celestial objects. It is not too much to say that whilst the designation "Dumb-bell" is fairly appropriate in describing this object as

seen in telescopes up to 6 or 8 or more inches of aperture, yet this feature becomes inappreciable altogether in the giant telescopes of the present day, which run to 20, or 30, or 40 inches of aperture. Roberts's photograph of this object is visually almost irreconcileable with the older drawings, in which the "Dumb-bell" idea is the dominant one.

The Southern hemisphere contains two objects which must not be passed over in treating of nebulæ. These are the "Magellanic Clouds," or the "Nubecula Major" and "Nubecula Minor"—both of them terms recalling the cloudlike appearance of these objects, the words "major" and "minor" relating of course to their size. Both are at no great distance from the Pole, the "Greater Cloud" being in the constellation Dorado, and the "Lesser Cloud" in Toucan. They are of a somewhat oval shape and visible to the naked eye, but the smaller one disappears in strong moonlight. Sir John Herschel describes them as consisting of swarms of stars, clusters, and nebulæ.

The distribution of the nebulæ in the heavens is a subject which has attracted the attention of many astronomers who have had theories to advance respecting such topics, or who have written on the constitution of the Universe. But I do not know that it can be said that very much light has been thrown upon the questions of this character which have presented themselves for solution. One thing is very noteworthy, and no doubt is significant, but we do not know of what it is significant. The distri-

bution of the nebulæ over the heavens is extremely unequal. They congregate in a zone which crosses the Milky Way at right angles. The majority are to be found in a zone which scarcely embraces an eighth part of the heavens. The constellation Virgo is where they are gathered together in greatest number, and they abound also in the neighbouring constellations of Leo, Ursa Major, Camelopardus, Draco, Boötes, Coma Berenices, and Canes Venatici. In the part of the heavens almost exactly opposite to these constellations—that is to say, in Pegasus, Andromeda, and Pisces—they are also numerous. The inequality in the distribution of the nebulæ will perhaps be best brought home to the reader by considering how they are distributed in hours of Right Ascension. Of the 5079 clusters and nebulæ entered in Sir John Herschel's Catalogue of 1864 whilst the XIXth and XXth hours contain only 79 and 90 objects respectively, the XIth hour contains 421 and the XIIth 686. The last-named hour is that which embraces a large part of Virgo. The regions of the heavens which lie nearest to the Milky Way are the poorest in nebulæ, while they are most abundant around the Poles of that great and mysterious belt. In the Southern hemisphere the nebulæ are more uniformly spread over the zone which surrounds the South Pole. On the other hand, their aggregate number is smaller; nevertheless there are 2 magnificent regions there which alone contain nearly 400 nebulæ and star clusters.

It is a remarkable fact that almost all the

nebulæ indicated by the spectroscope to be gaseous are situated either within the Milky Way or closely adjacent thereto; whilst in the regions near the Poles of the Milky Way gaseous nebulæ are wanting, though other nebulæ are abundant.

The reader will remember what has already been said respecting the alleged variability of great nebula in Orion, of the nebula surrounding η Argûs, and of the "Omega" nebula in Vulpecula. Subject to the remarks already made in dealing with those 3 nebulæ, it is to be considered that, though there are such things as variable stars, no variable nebulæ are known to exist.

CHAPTER XVII.

THE MILKY WAY.

Though when one gazes at the Milky Way there is, in a certain sense, not much to see (or at least not much which one can realise), yet an attentive consideration of it with the assistance of a telescope brings to light a vast variety of details of the highest interest. How it presented itself to our English forefathers is sufficiently shown by Milton's well-known description of it (*Paradise Lost*, bk. vii. v. 577–81) as—

> "A broad and ample road, whose dust is gold
> And pavement stars, as stars to thee appear,—
> Seen in the Galaxy, that Milky Way
> Which nightly, as a circling zone, thou seest,
> Powdered with stars."

From the foregoing it will appear that Wordsworth was not displaying his own original genius when (in *Dion*) he spoke of—

> "Heaven's broad causeway paved with stars."

Perhaps before I recount any further speculations of this character we had better consider the Milky Way descriptively. So far as I know the only astronomer who has written on it, and been able to do so from personal study of it in both hemispheres of the earth, is Sir John Herschel. It is obvious that no description of such an object can be adequately framed merely by the collocation of accounts prepared piecemeal, but that there is required the pen of a man who has taken notes of it at first hand round its entire circumference. I make no apology, therefore, for borrowing, in a simplified and condensed form, Sir John Herschel's description of the Milky Way.

Following the line of its greatest brightness, as well as its varying breadth permits, its course conforms as nearly as may be to that of a great circle inclined about 63° to the equinoctial, and cutting that circle in R.A. 6h. 47m., and 18h. 47m., so that its poles are in R.A. 12h. 47m., Decl. N. 27° and R.A. 0h. 47., Decl. S. 27°. Throughout the region where it is sub-divided this great circle runs as it were in between the 2 great streams of galaxy matter, with a nearer approximation, however, to the brighter and continuous stream. If we trace the Milky Way in the order of R.A., we find it traversing Cassiopeia,

its brighter part passing about 2° to the North of δ. Passing thence between γ and ε it sends off a branch, southwards and preceding, towards α Persei, conspicuous as far as that star, prolonged faintly towards ε Persei, and possibly traceable towards the Hyades and Pleiades. The main stream, however (which is here very faint), passes on through Auriga over ε, ζ, η, preceding Capella, between the feet of Gemini and the horns of Taurus (where it intersects the ecliptic nearly in the solstitial colure), and thence over the club of Orion to the neck of Monoceros, intersecting the equinoctial in R.A. 6h. 54m. Up to this point, from the offshoot in Perseus, its light is feeble, but thenceforward it gradually brightens up, and from the shoulder of Monoceros and over the head of Canis Major it presents a broad, moderately bright, very uniform and, to the naked eye, starless stream up to the point where it enters the prow of Argo nearly on the Southern Tropic. Here it again subdivides (about the star *m* Puppis), sending off a narrow and winding branch on the preceding side as far as γ Argûs, where it abruptly terminates.

The main stream pursues its southward course to the 33rd parallel of South Declination, where it diffuses itself broadly and again subdivides, opening out into a wide fan-like expanse, nearly 20° in breadth, formed of interlacing branches, all of which terminate abruptly, in a line drawn nearly through λ and γ Argûs.

Here the continuity of the Milky Way is interrupted by a wide gap, and where it recommences on the opposite side it is by a somewhat

similar fan-shaped assemblage of branches which converge upon η Argûs. Thence it crosses the hind feet of the Centaur, forming a curious and sharply defined semicircular cavity, and enters the Cross by a bright isthmus not more than 3° or 4° wide—this is the narrowest portion of the Milky Way. After this it immediately expands into a bright mass, enclosing α and β Crucis and β Centauri, extending almost up to α Centauri. In the midst of this bright mass, and occupying about $\frac{1}{2}$ its breath, occurs a singular dark pear-shaped vacancy about 8° long and 5° broad, very conspicuous, and for several centuries past called the "Coal-sack"—a name given to it by the early navigators. In this vacancy there is only one very small naked-eye star, though there are telescopic stars. The striking blackness is the effect of contrast with mass of bright matter by which the black area is surrounded. This is the place of the nearest approach of the Milky Way to the South Pole. Throughout all this region its brightness is very striking, and when compared with the more Northern portion, the course of which has been already traced, conveys strongly the idea of greater proximity, and would almost lead to a belief that our situation as spectators is separated on all sides by a considerable interval from the dense body of stars composing the Galaxy, which in this view would have to be considered as a flat ring of immense and irregular breadth and thickness within which we are eccentrically situated, nearer to the Southern than to the Northern part of its circuit.

At α Centauri the Milky Way again subdivides,

sending off a great branch of nearly half its breadth, but which thins off rapidly, at an angle of 20° with its general direction, towards the preceding side to η and *d* Lupi, beyond which it loses itself in a narrow and faint streamlet. The main stream passes on, increasing in breadth, to γ Normæ, where it makes an abrupt elbow and again subdivides into one principal and continuous stream of very irregular breadth and brightness on the following side, and a complicated system of interlaced streaks and masses on the preceding, which covers the tail of Scorpio, and terminates in a vast and faint effusion over the whole extensive region occupied by the preceding leg of Ophiuchus, extending Northwards to a parallel of 13° of South Declination, beyond which it cannot be traced, a wide interval of 14° free from all appearance of nebulous light separating it from the great branch on the North side of the equinoctial of which it is usually represented as a continuation.

Returning to the point of separation of this great branch from the main stream at α Centauri, let us now pursue the course of the latter. Making an abrupt bend to the following side it passes over ι Aræ, θ and ι Scorpii, and γ Telescopii to γ Sagittarii, where it suddenly collects into a vivid oval mass about 6° in length and 4° in breadth, so excessively rich in stars that a very moderate calculation makes their number exceed 100,000. Northward of this mass this stream crosses the ecliptic in longitude about 276°, and proceeding along the bow of Sagittarius into Antinoüs, has its course rippled by 3 deep

concavities separated from each other by remarkable protuberances, of which the larger and brighter (situated between the stars 3 and 6 Aquilæ) forms the most conspicuous patch in the Southern portion of the Milky Way visible in English latitudes.

Crossing the equinoctial at the XIXth hour of R.A. it runs in an irregular, patchy, and winding stream through Aquila, Sagitta, and Vulpecula up to Cygnus. At ε Cygni its continuity is interrupted, and a very confused and irregular region commences, marked by a broad, dark vacuity not unlike the "Coal-sack" of the Southern hemisphere, occupying the space between ε, α and γ Cygni, which serves as a kind of centre from which 3 great streams diverge. Of these streams one has been already traced; a second, which is a continuation of the first (across the interval) from α Cygni northwards, between Lacerta and the head of Cepheus to the point in Cassiopeia, whence we set out; and a third branching off from γ Cygni, very vivid and conspicuous, running off in a southerly direction through β Cygni and s Aquilæ, almost to the equinoctial, where it loses itself in a region thinly sprinkled with stars, where in some maps the modern constellation Taurus Poniatowskii is placed. This is the branch which, if continued across the equinoctial, might be supposed to unite with the great southern effusion in Ophiuchus already noticed. A considerable off-shoot or protuberant appendage is also thrown off by the northern stream from the head of Cepheus directly towards the Pole occupying

the greater part of the trapezium formed by α, β, ι and δ of that constellation.

In connection with the Milky Way a large amount of speculation has been indulged in, but as Gore well remarks:—"Many attempts have been made to form a satisfactory theory of the construction of the Milky Way, but these efforts have been hitherto attended with but little success. This is not surprising, as the problem is evidently one of great difficulty." Thomas Wright, of Durham, was the first modern speculator. He started, about 1734, a theory which, in a more matured form and worked out with better materials, was put forward by Sir W. Herschel about 1784 and became widely known as the "Stratum theory" of the Milky Way, or, as some have called it, the "Cloven disc theory." Briefly, his idea was that the stars were not indifferently scattered through the heavens, but were rather arranged in a certain definite stratum, comprised between 2 plane surfaces parallel to and near each other but prolonged to immense distances in every direction, the thickness of which stratum, as compared with its length and breadth, was inconsiderable; and that the Sun occupies a place somewhere about the middle of its thickness, and near the point where it subdivides into 2 principal streams inclined to each other at a small angle. This theory is not accepted in the present day,* and other theories have been put

* Proctor asserted that it was even given up by its author, but Sir John Herschel, writing more than half a century afterwards, reproduced it without any hint that it

forth. Proctor, whose strong point was running down his rivals, suggested that the form of the Milky Way was that of a spiral, but this notion has been demolished by Sutton. Gould is disposed to consider the Milky Way to be "the resultant of two or more superposed galaxies," whatever that may mean. All things considered, Gore's words are eminently wise:—"The Copernicus of the sidereal system has not yet appeared, and it may be many years, or even centuries, before this great problem is satisfactorily solved." In point of fact, for more than 2000 years astronomers (and others) have been speculating as to the origin and nature of the Milky Way. Metrodorus considered it to be the original course of the Sun abandoned by him after the bloody banquet of Thyestes; others thought that it pointed out the place of Phaëton's accident, whilst yet another class regarded it as being made up of the ears of corn dropped by Isis in her flight from Typhon. It seems hardly consonant with our prosaic nineteenth-century thoughts to transcribe such rubbish as this, yet these and kindred fables and fancies have taken deep root in the human mind, though probably it is true that they do not possess the ascendancy which they did even 50 years ago. There were, however, others of the ancients who, though no doubt painfully ignorant of physical science, as tested by our modern standards, and impregnated with ideas of the most ridiculous and

had been abandoned by his father, and a son is a better authority as to his father's opinions than a mere stranger, as Proctor was.

fantastic character, did, at anyrate, do their best, according to their lights. For instance, when Aristotle imagined the Milky Way to be the result of gaseous exhalations from the earth which were set on fire in the sky, who shall say that he did not prefigure Huggins's conclusion that certain of the nebulæ are nought else but blazing masses of hydrogen or other terrestrial gases? It is more difficult, however, to find a modern counterpart for the idea of Theophrastus, that it is the soldering together of 2 hemispheres; or for the conception of Diodorus, that in gazing at the Milky Way we see a dense celestial fire which shows itself through the clefts which indicate that 2 hemispheres are about to burst apart. It is, however, interesting to come upon speculations by Democrates and Pythagoras that the galaxy was neither more nor less than a vast assemblage of stars. Ovid speaks of it as a high-road "whose groundwork is stars." Manilius, who posed as an astronomical writer about the first century of the Christian Era, and who was probably a Roman, uses similar language. In a poem which he wrote called the "Astronomicon," and which has been more than once, I think, rendered into English, we find the following allusion to the Milky Way:—

> "Or is the spacious bend serenely bright
> From little stars, which there their beams unite,
> And make one solid and continued light?"

It is not a little curious how widely spread, both as regards time and place, is the associa-

tion of the idea of *milk* with the Milky Way; and though, no doubt, it may be a case of one language supplying a word which others borrowed and translated, yet this would hardly have been done if the underlying idea had not proved acceptable. The Greek name was Γαλαξίας or Κύκλος γαλακτίκος, which the Romans converted into *Circulus Lacteus* or *Orbis Lacteus*, whence no doubt our "Milky Way." At the same time our English ancestors had several independent names of their own. Amongst these were "Jacob's Ladder," "The way to St. James's," and "Watling Street." The existence of these names supplies another proof, if one were wanted, that the cardinal facts and features of a science like astronomy often take a much deeper hold over the popular mind than might be expected.

CHAPTER XVIII.

THE APPLICATION OF THE SPECTROSCOPE TO THE STARS AND NEBULÆ.

THE subject covered by the above heading has of late years grown to be a very large one, and it will only be possible to exhibit here a bare outline. The spectroscope was first applied to the stars by Fraunhofer about 1814. His apparatus consisted only of a small prism placed in front of the object glass of a telescope belonging to a theodolite. The intervention of the prism changed the image of the star from the bright point which it showed when viewed by the

telescope alone, into a narrow, bright line which exhibited all the colours of the rainbow in their customary order, from red at one end to blue at the other. The formation of the spectrum, as this many-coloured line is called, is easily understood. The light from a star consists, not of rays of one colour alone, but of rays of an infinite number of different colours. These, in the ordinary course of things, follow the same path, enter the telescope together, come practically to the same focus, or nearly so, and produce a single and colourless image of the star, because the combination of all the different colours yields the sensation which we term white light. But when the light of a star passes through a prism it becomes bent out of its course, and the several different colours are each differently affected, some being more bent from the original straight line than others. Each separate coloured ray then produces a separate coloured image of the star, and these images no longer converge together to the same point, but fall into position side by side, overlapping each other.

Fraunhofer found, however, in the case of the stars, as he had previously found on examining the light of the sun, that the spectra of the stars were not quite complete, and instead of the coloured line being absolutely continuous from the red end to the violet end, it was interrupted here and there by narrow dark spaces. These spaces, in the case of the planets Mars and Venus, corresponded precisely with those spaces which he had already detected in the spectrum of the sun, and this was natural, since the

planets only reflect to us the light which they receive from the sun. But the gaps or dark lines in the spectra of different stars were not precisely identical with those to be traced in the solar spectrum, and, moreover, the spectra of different stars were different.

This was an important discovery, for it proved that the source and cause of these dark lines depended on the sun or on the various stars themselves, as the case might be; and was not due to anything in our atmosphere, or in celestial space, for in such case all the lines would have been alike. Certain particular lines were indeed traced to our atmosphere as they were invariably seen in the spectrum of any celestial body when it was near the horizon, and was therefore being viewed through a great thickness of terrestrial atmosphere.

Fraunhofer did not arrive at any explanation of the cause of these lines, and a generation passed away before Kirchhoff, in 1859, proved that a number of the solar lines were due to the presence in the sun's atmosphere of the glowing vapours of various metals, of which sodium and iron seemed to be the chief.

The presence of a pair of bright lines in the orange-yellow portion of the spectrum of a candle flame had long been noticed. It had been proved that these were due to sodium, and it had been shown that they corresponded precisely in position to a pair of dark lines known as the D lines in the spectrum of the sun. Kirchhoff succeeded in showing that a glowing gas which, at a given temperature,

gives off light of a particular tint (or rather of a particular wave-length) possesses also at that temperature the power of absorbing light of that same wave-length. The surface of the sun (the "photosphere," as it is technically called) emits light of every colour, but superposed on it are the luminous vapours of various metals. These vapours, could we but see them alone, would give us only light of certain particular colours—their spectra would be spectra of bright lines. But, looking through them at the solar photosphere (which lies below), these gases shut off from us light emanating from the photosphere of precisely the same quality as they themselves emit. We find, therefore, the solar spectrum crossed by dark lines, which correspond to the bright lines of the gases of the solar atmosphere. The conclusion of the whole matter is that whilst the two D lines show the presence of sodium, other lines, known as C, F, G^1, and h show the presence of hydrogen; whilst iron, magnesium, and other elements have also been severally detected in turn.

The same principle has now been applied to the spectra of stars. In their case, as in the case of the spectrum of the sun, the bright background of the continuous spectrum shows the presence of a stellar photosphere, the dark lines crossing it the presence of particular gases in the stellar atmosphere. But the work of identifying these gases in connection with the stars was one of far greater difficulty than it had been in the case of the sun, owing to the light even of the brightest stars being comparatively so feeble.

This task was, however, undertaken by Huggins and Miller with the utmost skill and patience, and hydrogen, sodium, magnesium, iron, calcium and other elements which had been previously detected in the sun were shown to exist in the atmospheres of Arcturus, Aldebaran, and several other stars.

For such researches as those of Huggins and Miller the object-glass prism of Fraunhofer was quite unsuited, and a slit spectroscope was adopted. In this a very narrow slit occupies the focus of the telescope, so that the image formed by the telescope falls upon it. The slit is also in the focus of a small object-glass placed behind it, called the collimator, which renders the rays of light coming from the star parallel to each other. The rays then pass through one or more prisms and so become dispersed, the differently coloured rays undergoing a different amount of bending out of their course. Finally the spectrum thus produced is viewed by means of a small telescope. As the normal image of a star is only a point the resulting spectrum is only a line, and a small breadth has to be imparted to it by means of a cylindrical lens before it can be successfully observed.

A labour of a different character was being undertaken by Secchi at about the same time that Huggins and Miller were at work. This distinguished Italian physicist found that though the spectra of different stars differed in character, these differences might easily be reduced to no more than 3 or 4 simple types. Rutherfurd had made a similar suggestion a little earlier, but

Secchi was the first to carry out a systematic spectroscopic examination of any considerable number of stars. More recently, other and more detailed classifications have been proposed by Vogel and by Lockyer and—as regards the photographs of stellar spectra—by Pickering, but these have in no way superseded Secchi's scheme of classes; they have supplemented it rather than replaced it.

Secchi divided the stars into 4 principal groups, which he designated "Types":—(I.) The white or bluish stars, of which Sirius may be taken as the type. These stars yield spectra with the lines of hydrogen very broad and dark, but the lines of the metals faint and difficult to see, or altogether absent. (II.) The yellow stars, of which our Sun, Arcturus, and Capella may be taken as the chief types. The spectra of these show the lines of hydrogen, but not so broadly or prominently as in the case of the Ist type; the metallic lines are, however, on the other hand, numerous and distinct. (III.) The orange stars, of which α Orionis, α Herculis, and the variable star *Mira* Ceti are types. This class also includes divers variable stars of long or irregular period. The spectra are crossed by a number of dark bands, very dark and sharp on the side nearest the blue, and shading off gradually towards the red end. (IV.) The red stars, none of which are brighter than 5th magnitude. These have spectra crossed principally by 3 dark bands, due to the absorption of carbon, and shaded the reverse way to those of the IIIrd type.

A number of small stars, distributed along the axis of the Milky Way, and commonly called the "Wolf-Rayet" stars, from the two French astronomers who found the first examples, are now considered, in accordance with a suggestion of Pickering's, to form, together with the planetary nebulæ, a Vth general type. These show very characteristic spectra, the background being of irregular brightness and crossed by two bright lines in the yellow, by another in the light green, and by a distinctive bright band in the blue.

There are also a few stars which can scarcely be brought under any of the foregoing five heads. For instance, many of the stars in Orion have the hydrogen as well as the metallic lines narrow and faint; they can therefore hardly be placed under either the Ist or IInd types. And it may be added that γ Cassiopeiæ, β Lyræ, and a few other stars show the hydrogen lines bright.

Secchi's catalogue contained about 500 stellar spectra, but this number has been very largely increased by Vogel, who has informed us concerning the spectra of about 4000 stars; whilst Konkoly has dealt with about 2000 stars. All the foregoing were the result of direct eye observation, but a fuller survey has since been accomplished by means of photography. Huggins at an early period applied photography to the study of stellar spectra, and discovered thereby a remarkable series of broad, dark lines in the ultra-violet region of spectra of stars of the Sirius type. Dr. Henry Draper worked on similar lines at about the same time, and after his death his widow placed ample funds at the

disposal of the Harvard College observatory for further researches to be carried on in memory of her late husband. One of the results of her generosity, and of Pickering's skilful use of it, is the "Draper Catalogue," a classified catalogue of the photographed spectra of more than 10,000 stars. The classification adopted is somewhat more detailed than Secchi's, but proceeds on essentially the same lines.

In a previous chapter (XII.) I have said a good deal about that remarkable class of objects commonly called the temporary stars, or *Novæ*—stars which have suddenly come into view and have then rapidly faded away. Only a few instances have occurred since the application of the spectroscope to stellar observation, and the stars have all been much less bright and enduring than Tycho's famous star of 1572, but striking characteristics have been exhibited by each of those which have been spectroscopically treated.

The spectrum of T Coronæ in 1866 showed, besides a continuous spectrum crossed by dark lines, a number of bright lines, amongst which those of hydrogen were clearly to be noticed. In *Nova* Cygni in 1876, again, a number of bright lines were seen superposed on a continuous spectrum. These bright lines appeared on the whole to correspond to those of the solar chromosphere (the narrow red fringe seen surrounding the sun's disc during a total solar eclipse). The hydrogen lines, and a characteristic line in the yellow, near the D lines of sodium, and called D_3 (or the "Helium" line),

were the most conspicuous. It must be noted in this connection that the hydrogen lines with the D_3 line are also the chief lines exhibited by the "red flames," or prominences," which are often seen to rise from the solar chromosphere to heights of a 100,000 miles or more. It follows from this, therefore, that T Coronæ and *Nova* Cygni seemed to offer evidence that stars are not only sometimes composed of the same elements as the sun, and, like it, possess photospheres surrounded by absorbing gases, but also that they possess chromospheres and prominences, so that, in point of fact, the sudden development of brilliancy recorded in the case of these 2 stars was really in the nature of a prodigious chromospheric outburst.

Nova Cygni, however, underwent further changes. When its continuous spectrum had nearly faded out the aspect of the spectrum that remained greatly resembled that of the Wolf-Rayet stars. Later still, in the autumn of 1877, the light of the star appeared concentrated in a single bright line, apparently the line characteristic of the nebulæ.

Near the centre of the great nebula in Andromeda a new star became visible in August, 1885. Its spectrum was practically continuous.

Two other *Novæ* have yet to be mentioned, *Nova* Aurigæ and *Nova* Normæ, the last named, apparently a faint copy of the first. *Nova* Aurigæ stands out as perhaps the most interesting and most perplexing object yet studied by aid of the spectroscope. Discovered by Dr. Thomas Anderson on January 24, 1892,

but recorded by the automatic stellar camera of Harvard College on December 10, 1891, it showed, when subjected to spectroscopic analysis, the twofold spectrum seen in T Coronæ and *Nova* Cygni, a continuous spectrum crossed by dark lines, and a spectrum of bright lines, amongst which those of hydrogen were conspicuous, together with many of the principal lines of the solar chromosphere.

The star diminished in brightness very quickly after March 16, 1892, and was unfavourably placed for some months. When it was examined afresh on August 17 by the Lick observers, it was found to have undergone a partial revival, and, as in the case of *Nova* Cygni, they thought its spectrum closely resembled that of a planetary nebula. Huggins, however, did not regard this conclusion as fairly established. The spectrum showed, it is true, two bright bands near the positions of the two chief nebular lines, but the bands were really groups of bright lines, extending over a considerable length of the spectrum. The most striking feature of the spectrum of *Nova* Aurigæ was the displacement of its lines. As first seen, the bright hydrogen lines were accompanied by dark absorption lines, manifestly due to the same element, but displaced towards the violet as compared with the bright lines. Photographs of the spectrum revealed further details. Many of the dark lines carried a fine bright line upon them; many of the bright lines could be resolved into two or three components. Here, then, there was at least a double hydrogen

spectrum: one of dark lines, the other of bright lines, the two displaced with regard to each other. Possibly there were several such distinct spectra. How were their displacements with regard to each other to be explained?

Doppler, in 1843, had shown that the motion of a source of light towards the observer must cause a shortening of the intervals between the waves of light. In other words, light of a given special wave-length would have that wave-length diminished, and the light would appear to have shifted its place in the spectrum towards the blue end if the source of the ligh were in motion towards us. If we adopt th explanation of the composite spectrum of *No* Aurigæ it follows that that star must have consisted of two or more bodies moving in different directions in the line of sight with a most amazing velocity. The body giving the dark absorption lines would appear to have been approaching our system at a speed of 400 or 500 miles a second, and the body giving the bright lines to have been receding at a speed of about 300 miles a second.

This is scarcely the place to bring forward in detail theories to explain these complicated spectra. The two most favoured are the "tidal theory," which supposes that the near approach of two great stars to each other has given rise to immense tidal waves of highly heated gas, and the "cosmical cloud theory," according to which these *Novæ* are due to the rush of a swiftly moving star through a nebula.

Doppler's principle (as has already been briefly mentioned in a previous chapter) had

been applied to a different problem by Huggins in 1867, who carefully compared the position of the green line of hydrogen as given by a vacuum tube, with that of the same line in the spectrum of Sirius. Later on he examined the spectra of a number of stars, and calculated from the amounts and direction of the displacement of the lines in their spectra, the speed at which the separate stars were moving towards us, or away from us in the line of sight. This research was then taken up at Greenwich and at Rugby, but with insufficient means. Lastly, Vogel pressed photography into the service, and made some very successful observations on about 50 stars.

One result of Vogel's work was the discovery of "spectroscopic double stars." The variable star, Algol, had long been suspected to have a dark companion, which by transiting before its primary caused a partial eclipse every 69 hours. Vogel now conclusively showed that this was the case, for Algol was moving round the centre of gravity of the pair in precisely the time required, and the diameter, mass, distance from its primary, and speed in its orbit, of the unseen companion, were all computed.

Spica Virginis proved to be another close double, though in this case the companion does not obscure the bright principal star. Indeed, it is possible that it is as bright as the 3rd magnitude.

In some cases a "spectroscopic double" is composed of two stars of nearly equal brightness. This is the case with ζ Ursæ Majoris

and β Aurigæ, which were discovered by Pickering a little before Vogel's proof of the existence of the companion of Algol. The two stars which make up β Aurigæ revolve in an orbit which is but little inclined to the line of sight. Consequently at one time one star will be approaching us in its orbit whilst the other is receding. The lines due to the first star are displaced towards the blue, and those of the second towards the red, and the lines in the compound spectrum are therefore double. A little later both bodies are moving across the line of sight, and therefore are neither approaching us or receding from us, so that the lines of the two stars exactly coincide. The period in the case of this star is nearly 4 days.

Another probable "spectroscopic double" is the variable star β Lyræ. This star (as we have already seen) goes through its changes in a little less than 13 days, having two maxima and two minima. Its spectrum shows broad, dark bands, due to hydrogen, besides bright lines, which change their appearance and position from time to time. It has been suggested that the system consists of two stars of unlike spectra revolving round each other, and partially eclipsing each other as they cross the line of sight. The changes of the spectrum are, however, very complicated, and have not yet been completely studied, and so simple an explanation appears scarcely adequate.

A very promising and important study is that of the distribution of the different types of stellar spectra. For this the available ma-

terial is as yet insufficient. Nevertheless, the Draper catalogue, and the catalogues of Vogel and Konkoly, have enabled some first approximations to be made. It appears, from a consideration of such binary stars as have been spectroscopically examined, that the Ist or Sirius type of stars are much less dense relatively to their brightness than the Solar stars, or are intrinsically brighter relatively to their density. The IInd type of stars, *i.e.*, the Solar stars, and to a less degree the IIIrd type of stars, appear to be pretty evenly distributed over the sky. The Ist, or Sirius type, shows a distinct disposition to aggregation towards the Milky Way, whilst, as already pointed out, the Wolf-Rayet stars cluster along its axis. The proper motions of the Sirius stars appear to be smaller than those of the Solar stars, which from this and other reasons may be supposed to be on the average nearer to us than the Sirius stars. If the Solar type stars be divided into two classes, according to their greater resemblance to Capella and Arcturus respectively, the former class appears to have a larger average proper motion than the latter, and may therefore be supposed to be the nearer stars. The entire subject, however, needs much fuller investigation before any great weight can be attached to these provisional conclusions. The completion of the Draper catalogue by the publication of the results of the survey of the southern heavens carried out at Arequipa, in Peru, under the direction of the Harvard astronomers, will constitute the next important forward step.

The first observation of the spectrum of a nebula was made by Huggins in August, 1864. The object examined was the small, bright, planetary nebula in the pole of the ecliptic, 37 ♅ IV Draconis, to which some allusion has already been made. The first scrutiny revealed the fact that there existed an immense difference between its spectrum and an ordinary stellar spectrum. In place of the usual continuous spectrum only three isolated bright lines were seen—a proof of the presence of luminous gas. In other words, the object was a true nebula, that is, a mass of glowing gas, and not a star cluster, seeming to be nebulous only on account of its distance.

Of the three lines, one, the faintest, was evidently due to hydrogen. The other two have not yet been identified, but the brightest is very near one of a pair of green lines in the spectrum of nitrogen, and has hence been sometimes spoken of as the "nitrogen line." Other lines due to hydrogen have since been observed in various nebular spectra, together with the well-known chromospheric line D_3. A number of other lines have also been detected in the visual spectrum with extreme difficulty by different observers, and many more by means of photography in the violet and ultra-violet regions. The sources of these lines have not yet been ascertained, and in a great number of the fainter spectra the line in the green near the nitrogen pair, which is especially to be regarded as the typical nebular line, is alone visible.

The problem of the motions of the nebulæ in

the line of sight has been attacked by Keeler at the Lick Observatory. He has measured the displacement of the chief nebular line in the spectra of the nebulæ, and has obtained evidence of movements varying from a speed of about 40 miles per second of approach, to about 30 miles per second of recession.

Several of the nebulæ, as, for example, the great nebula in Andromeda, show continuous spectra. But many of those that give a spectrum of bright lines give also a faint, continuous spectrum. The great nebula of Orion is one of the latter class, though Huggins considers that the seemingly continuous spectrum is resolvable into lines. Other nebulæ show bright lines only, without any trace of continuous spectrum.

In the case of the great nebula in Orion Huggins has secured some photographs of exceptional interest, which show that the stars of the "trapezium" are not merely apparently in the nebulæ, but really so, for a number of bright lines (one in particular, with a wave-length of 3730 "tenth metres") were observed both in the continuous spectrum of two of the trapezium stars, and in the spectrum of the nebulæ in their immediate neighbourhood. A later photograph, taken in 1889, in which the slit of the spectroscope was pointed near to the trapezium, but not actually across it, failed to show the 3730 line, which would thus appear to be typical only of the regions of the nebulæ close to the stars. It would seem probable, therefore, that these stars are involved in the nebulæ.

The subject of spectroscopic observations of the stars and nebulæ is a growing one, but we have yet much more to do before we can much more learn.

APPENDIX I.

TABLE OF THE CONSTELLATIONS.

By the entries in the column headed "Centre" it is meant to be inferred that a line of Right Ascension and a line of Declination taken off the map will intercept at a point which may be regarded as about the centre of the constellation. This, however, is only true of the more compact constellations, for there are some, like Draco, Cetus, and Argo, which are so long and straggling that they extend over several hours of R.A. When, therefore, I state that the constellations are here arranged in the order of R.A., the statement must be regarded as needing some qualification in many cases. In the column of "Declination" + means North, and — South.

Name of Constellation.	Centre.	
	R.A.	Decl.
	h. m.	°
Pisces	0 20	+ 10
Sculptor [Apparatus Sculptoris]	0 30	– 35
Andromeda	0 40	+ 38
Phœnix	1 0	– 48
Cassiopeia	1 0	+ 60

Name of Constellation.	Centre.	
	R.A.	Decl.
	h. m.	°
Cetus	1 45	− 12
Triangulum	2 0	+ 32
Fornax [Chemica]	2 25	− 33
Aries	2 30	+ 20
Hydrus	2 40	− 72
Perseus	3 20	+ 42
Horologium	3 20	− 52
Reticulum [Rhomboidalis]	3 50	− 63
Eridanus	3 50	− 30
Taurus	4 30	+ 18
Cælum [Cæla Sculptoris]	4 40	− 42
Dorado	5 0	− 60
Orion	5 20	+ 3
Lepus	5 25	− 20
Pictor [Equleus Pictoris]	5 30	− 52
Mensa [Mons Mensa]	5 40	− 77
Columba [Noachi]	5 40	− 34
Camelopardus	5 40	+ 70
Auriga	6 0	+ 42
Canis Major	6 40	− 24
Gemini	7 0	+ 24
Monoceros	7 0	− 3
Canis Minor	7 30	+ 6
Argo [Puppis]	7 40	− 32
Lynx	7 50	+ 45
Argo	8 0	− 40
Cancer	8 30	+ 20
Argo [Carina]	8 40	− 62
Volans [Piscis Volans]	8 40	− 69
Argo [Malus]	9 0	− 30
Argo [Vela]	9 30	− 45
Antlia Pneumatica	10 0	− 35
Sextans	10 10	− 1
Leo Minor	10 20	+ 33
Leo	10 30	+ 15
Chamæleon	10 40	− 78
Hydra	11 0	− 12

Name of Constellation.	Centre.	
	R.A.	Decl.
	h. m.	°
Ursa Major	11 0	+ 58
Crater	11 20	− 15
Crux	12 20	− 60
Corvus	12 30	− 18
Musca Australis	12 30	− 68
Coma Berenices	12 40	+ 27
Canes Venatici	13 0	+ 40
Centaurus	13 20	− 47
Virgo	13 20	− 2
Boötes	14 35	+ 30
Circinus	14 50	− 63
Lupus	15 0	− 40
Libra	15 10	− 14
Apus	15 30	− 76
Serpens	15 35	+ 8
Corona Borealis	15 40	+ 30
Triangulum Australe	15 40	− 65
Ursa Minor	15 40	+ 78
Norma	16 0	− 49
Draco	16 0	+ 60
Scorpio	16 20	− 26
Ara	16 50	− 55
Ophiuchus	17 10	− 4
Hercules	17 10	+ 27
Corona Australis	18 30	− 41
Scutum Sobieskii	18 30	− 10
Telescopium	18 40	− 52
Lyra	18 45	+ 36
Sagittarius	19 0	− 25
Pavo	19 10	− 65
Aquila (with Antinoüs)	19 30	+ 2
Sagitta	19 50	+ 18
Vulpecula et Anser	20 10	+ 25
Cygnus	20 30	+ 40
Delphinus	20 35	+ 12
Capricornus	20 50	− 20
Microscopium	21 0	− 37

Name of Constellation.	Centre.	
	R.A.	Decl.
	h. m.	°
Equuleus	21 10	+ 6
Indus	21 20	− 58
Piscis Australis	21 40	− 32
Cepheus	22 0	+ 70
Grus	22 20	− 47
Aquarius	22 20	− 13
Lacerta	22 25	+ 43
Pegasus	22 30	+ 17
Toucan	23 45	− 68
Octans	Polar	(South)

APPENDIX II.

LIST OF CELESTIAL OBJECTS FOR SMALL TELESCOPES.*

It is here assumed that a certain number of the readers of this volume may happen to possess a small telescope, and would be glad to direct it on celestial objects of interest if they knew where to look for some which were within the reach of their instruments. Hence the motive for the compilation of this catalogue, which may be said to represent the capacity of portable refracting telescopes of about 2 inches in aperture.

(1) DOUBLE OR COMPOUND STARS.

No.	Name of Star.	Right Ascension, 1890.	Declination, 1890.	Magnitudes of Components.	Distance between the Components.
		h. m. s.	° ′		″
1	β Toucani	0 26 30	− 63 34	Both 5	28
2	η Cassiopeiæ	0 42 26	+ 57 13	4 and 7½	5
3	γ Arietis	1 47 29	+ 18 45	4½ and 5	8
4	γ Andromedæ	1 57 8	+ 41 48	3½ and 5½	10: B. double.
5	θ Eridani	2 54 5	− 40 44	5 and 6	8
6	14 Aurigæ	5 8 14	+ 32 33	5 and 7½	14
7	23 Orionis	5 17 3	+ 3 26	5 and 7	31
8	δ Orionis	5 26 23	− 0 22	2 and 7	53
9	σ Orionis	5 33 3	− 2 38	4, 8 and 7	12 and 42: multiple.
10	11 Monocerotis	6 23 29	− 6 57	6½, 7 and 8	7, 9: (B.C. = 2·5)

* For a comprehensive general catalogue of objects of this kind, with full descriptions of each, see Admiral W. H. Smyth's "Cycle of Celestial Objects," 2nd ed., Oxford, 1881, price 12s.

No.	Name of Star.	Right Ascension, 1890.	Declination, 1890.	Magnitudes of Components.	Distance between the Components.
		h. m. s.	° ′		″
11	γ Volantis	7 9 40	— 70 19	5 and 7	13
12	α Geminorum	7 27 35	+ 32 7	3 and 3½	5
13	γ Argûs	8 6 8	— 47 0	2 and 6	42
14	54 Leonis	10 49 39	+ 25 20	4½ and 7	6
15	α Crucis	12 20 28	— 62 29	1½, 2 and 5	5, 90: quintuple
16	17 Comæ Ber.	12 23 25	+ 26 30	4½ and 6	145 [use low power]
17	γ Crucis	12 25 2	— 56 29	2 and 5	120
18	γ Virginis	12 36 5	— 0 50	both 4	5
19	α Can. Venat.	12 50 53	+ 38 54	2½ and 6½	20
20	ζ Ursæ Maj.	13 19 29	+ 55 30	3 and 5	14; Alcor, mag. 5, is distant 11¾
21	α Centauri	14 32 7	— 60 22	1 and 2	14
22	π Boötes	14 35 33	+ 16 53	3½ and 6	5
23	ξ Scorpii	15 58 19	— 11 4	4½ and 7½	7; A. also double
24	β Scorpii	15 59 2	— 19 30	2 and 5½	13; A. also double
25	ν Scorpii	16 5 36	— 19 10	4 and 7	40; both double 0·7, 2
26	36 (A) Ophiuchi	17 8 34	— 26 25	4½ and 6½	4
27	α Herculis	17 9 38	+ 14 30	3½ and 5½	4
28	ζ Lyræ	18 40 59	+ 37 29	5 and 5½	44
29	θ Serpentis	18 50 49	+ 4 3	4½ and 5	21
30	β Cygni	19 26 17	+ 27 43	3 and 7	34
31	α² Capricorni	20 11 57	— 12 53	3 and 4	376 [use low power]
32	β² Capricorni	25 14 50	— 15 7	3½ and 7	205
33	γ Delphini	20 41 33	+ 15 43	4 and 6½	11
34	β Cephei	21 27 14	+ 70 4	3 and 8	13
35	δ Cephei	22 25 5	+ 57 51	4½ and 7	40: A. var.

(2) CLUSTERS OF STARS AND NEBULÆ.

No.	Designation of Object.	Nature of Object.	Right Ascension.	Declination.
			h. m. s.	° ′
1	47 Toucani	Cluster	0 19 9	— 72 41
2	31 M. Andromedæ	Nebula	0 36 47	+ 40 40
3	The Nubecula Minor		0 48 41	— 73 58
4	103 M. Cassiopeiæ	Field of stars	1 25 56	+ 60 7
5	33 ℍ VI Persei	Double cluster	2 11 20	+ 56 38
6	η Tauri	Group of stars	3 40 56	+ 23 45
7	Nubecula Major		5 24 6	— 69 34
8	1 M. Tauri [" Crab "]	Nebula	5 27 51	+ 21 56
9	42 M. Orionis	Nebula	5 29 52	— 5 27
10	35 M. Geminorum	Cluster	6 2 4	+ 24 26
11	41 M. Canis Majoris	Cluster	6 42 13	— 20 37
12	" Præsepe " in Cancer	Cluster	8 33 55	+ 20 19
13	η Argûs	Nebula	10 40 47	— 59 6
14	κ Crucis	Cluster	12 47 7	— 59 45
15	ω Centauri	Cluster	13 20 10	— 46 44
16	3 M. Canum Venaticorum	Cluster	13 37 3	+ 28 55
17	5 M. Libræ	Cluster	15 12 57	+ 2 30
18	80 M. Scorpii	Cluster	16 10 26	— 22 43
19	13 M. Herculis	Cluster	16 37 45	+ 36 39
20	92 M. Herculis	Cluster	17 13 46	+ 43 15
21	14 M. Ophiuchi	Cluster	17 31 50	— 3 11
22	8 M. Sagittarii	Cluster	17 57 8	— 24 22
23	24 M. Scuti Sobieskii	Cluster	18 11 44	— 18 26
24	17 M. Scuti Sobieskii [" Horse-shoe "]	Nebula	18 14 16	— 16 14
25	22 M. Sagittarii	Cluster	18 29 28	— 23 59
26	11 M. Antinoï	Cluster	18 45 13	— 6 24
27	57 M. Lyræ	Annular neb	18 49 28	+ 32 53
28	27 M. Vulpecula [" Dumb-bell "]	Nebula	19 54 48	+ 22 25
29	15 M. Pegasi	Cluster	21 24 38	+ 11 40
30	2 M. Aquarii	Cluster	21 27 44	— 1 19

(3) SPECIAL STARS.

No.	Name of Stars.	Right Ascension, 1890.	Declination, 1890.	Mag.	Notes.
		h. m. s.	° ′		
1	o Ceti	2 13 47	— 3 28	Var.	Max. mag. 2: Fiery red. Invisible at Min.
2	α Ceti	2 56 31	+ 3 39	2½	Orange colour
3	β Persei	3 1 2	+ 40 31	Var.	Max. 2: Min. 4
4	5 Lyncis	6 17 12	+ 8 28	5½	Fiery red
5	μ Canis Majoris	6 51 3	— 13 54	5¼	Fiery red
6	20918 Lal. Hydræ	10 46 16	— 20 37	7	Copper coloured
7	β Libræ	15 11 5	— 8 58	2½	Pale green
8	α Scorpii	16 22 39	— 26 11	1	Fiery red
9	χ Cygni	19 46 20	+ 32 38	Var.	Max. 4: Min. invisible
10	μ Cephei	21 40 8	+ 58 16	Var.	Max. 4: Min. 6: Deep garnet colour
11	δ Cephei	22 25 5	+ 57 51	Var.	Max. 3¼: Min. 4½
12	8 Andromedæ	23 12 38	+ 48 24	5	Fiery red
13	30 Piscium	23 56 19	— 6 37	4½	Fiery red

GENERAL INDEX.

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